THE TAXONOMY AND PALAEOECOLOGY OF LOWER CARBONIFEROUS OSTRACODES AND PERACARIDS (CRUSTACEA FROM SOUTHWESTERN NEWFOUNDLAND AND CENTRAL NOVA SCOTIA)

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THE TAXONOMY AND PALAEOECOLOGY OF LOWER CARBONIFEROUS OSTRACODES AND PERACARIDS (CRUSTACEA) FROM SOUTHWESTERN NEWFOUNDLAND AND CENTRAL NOVA SCOTIA

by

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ABSTRACT

Middle Carboniferous sediments in the Maritime region of Canada were deposited in fluvial basins that were subjected to transgressive marine episodes often associated with hypersalinity.

A dominantly shallow marine, paraparchitacean ostracode fauna associated with palaeocopids, bairdiaceans and less common cytheraceans and myodocopids, as well as two peracarid genera has been recovered from sediments in southwestern Newfoundland and northern and central Nova Scotia. The paraparchitaceans are ubiquitous, and are even found in sediments containing synsedimentary gypsum. Two of the genera and four species are new.

Seven assemblages have been recognised based upon diversity, occurrence sedimentary facies and inferred environment.

In the least restricted carbonate environment, representatives of the following genera occur; *Kirkbya*, *Gortanella*, *Beyrichiopsis*, *Bairdiacypris* and two species of *Bairdia* associated with *Chamishaella*, *Monoceratina*, *Acratia*, *Acutiangulata* and *Polycope*. In a more restricted carbonate environment, *Chamishaella* is augmented by *Paraparchites*, *Shemonaella*, *Shishaella* and *Shivaella*; bairdiaceans are less common and the ornate palaeocopids are absent. An amphissitid, *Youngiella*, *Basslerella* and "*Neokloedenella*" occur with *Monoceratina*, *Acratia*, *Acutiangulata* and *Polycope* to give the total fauna. In the most restricted carbonate environment only representatives of the genera *Chamishaella*, *Gortanella* and *Acratia* occur.

Three hypersaline-related environments can be recognised. In the carbonate dominated environment, paraparchitaceans occur together with *Amphissites*, *Youngiella*, *Acratia*, "*Neokloedenella*" and *Acutiangulata* as well as the peracarid *Tealliocaris*. In the clastic-dominated hypersaline environment, *Chamishaella*, "*Neokloedenella*", *Acratia* and *Acutiangulata*, together with *Geisina* and "*Copelandella*" are the main elements of the fauna. Carbonate bands occurring within an evaporite sequence contain *Chamishaella*, *Paraparchites*, *Beyrichiopsis*, *Acratia* and *Acutiangulata*.

Species of the genera *Chamishaella*, *Acratia*, *Acutiangulata*, *Geisina* and "*Copelandella*" occur in a deltaic environment.

The Maritime Basin was a shallow embayment of the northern Hercynian Ocean, with a similar though not conspecific fauna to that of Western Europe. The lower diversity and high degree of dominance shown by the Maritime Basin faunas may be a function of several factors including the restricted circulation of sea waters, attendant hypersalinity as well as the limited duration and extent of the transgressive phases.

ACKNOWLEDGEMENT

There are many people without whose help this thesis would not have been possible, and whose contributions I am happy to acknowledge.

Primarily my thanks go to Dr. Lars Fahraeus, Noel James and Bob Stevens who together formed my supervisory committee, without their continued guidance this thesis would not be. I would also like to record my gratitude to Dr. Murray J. Copeland of the Geological Survey of Canada for suggesting the topic and being continually interested in my progress. Thanks also to Dr. Fred Schram at the Museum of Natural History, San Diego for advice on the peracarids, and Drs. Martin Bless at the Rijks Museum, Maastricht, and Greg Sohn at the United States Geological Survey for advice on the ostracodes. I should also like to thank Peter von Bitter and Hilary Plint-Geberl at the Royal Ontario Museum for providing siliceous residues from conodont samples. A vote of thanks could not be omitted to George Dix for his words of wisdom on the Port au Port Carboniferous, for the use of his thesis, and for introducing me to Willie Nelson - all of which were a great help. Other fellow grad-students whose support I would like to acknowledge are Greg Dunning and Bob Hildebrand for ideas, criticism and moral support. Jackie English is to be thanked for being my field assistant and contributing to an unforgettable summer - I'll never forget the moment you jumped across a ledge in Fischells Brook.....and missed; neither shall I forget your work as a cataloguer "par excellence". I also wish

to acknowledge some other people who have had a direct hand in the production of this tome: Hanny Muggeridge who drafted Text-fig. 6.29, Winston Howell who drafted the base-map for Text-fig. 5.1 and Wilf Marsh for his photographic skills. A special thank you goes to Carolyn Emmerson for teaching me how to use the scanning electron microscope, and for coaxing it through some very difficult times.

Debra Penny did a lot of the ostracode picking and my wife Elisabeth typed the thesis - though God alone knows why.

During my sojourn at St. Francis Xavier University I had the pleasure of meeting, working and generally living with Brendon "Face" Murphy whose help and encouragement have been deeply appreciated.

I should like to acknowledge the financial support of the University in the form of a Memorial University Fellowship to myself and the Natural Sciences and Engineering Research Council of Canada for a research grant to my supervisor.

To Ches and Ada Tuck I owe more than my thanks, for offering me their home as only a family can, during my residence in Newfoundland.

Finally we should not forget the meek and lowly, indeed this volume is perhaps dedicated to them. Something that never ceases to amaze me is the similarity of the ostracode to the coffee bean. If all the coffee beans that have given their all for the coffee I have drunk in the last three years were counted, would they equal or exceed the number of ostracodes that I have in my thesis collection? Thanks to Tim Hortons for the maple dip and the coffee, and Dairy Queen for the butterscotch milkshakes — without which many would have faltered.

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NOTE

Throughout the thesis the term "middle Carboniferous" is employed to avoid usage of the European term "Viséan" and the North American term "upper Mississippian" for strata in the Maritime basin. The term was used because although the sediments described herein are in North America, they possess a predominantly European fauna.

CHAPTER 1

INTRODUCTION

1.1 General aims.

The main aim of this study is a taxonomic documentation of ostracodes and peracarids occurring within the middle Carboniferous Codroy and Windsor Groups of Newfoundland and Nova Scotia (eastern Canada) respectively. A second aim is a consideration of the palaeoecological constraints affecting these faunas, including their resultant spatial distributions and community structures. The palaeobiogeographic significance of the ostracodes is discussed in relation to other contemporary faunas preserved elsewhere in the world, and examined in the light of an oceanic circulation model for the middle Carboniferous.

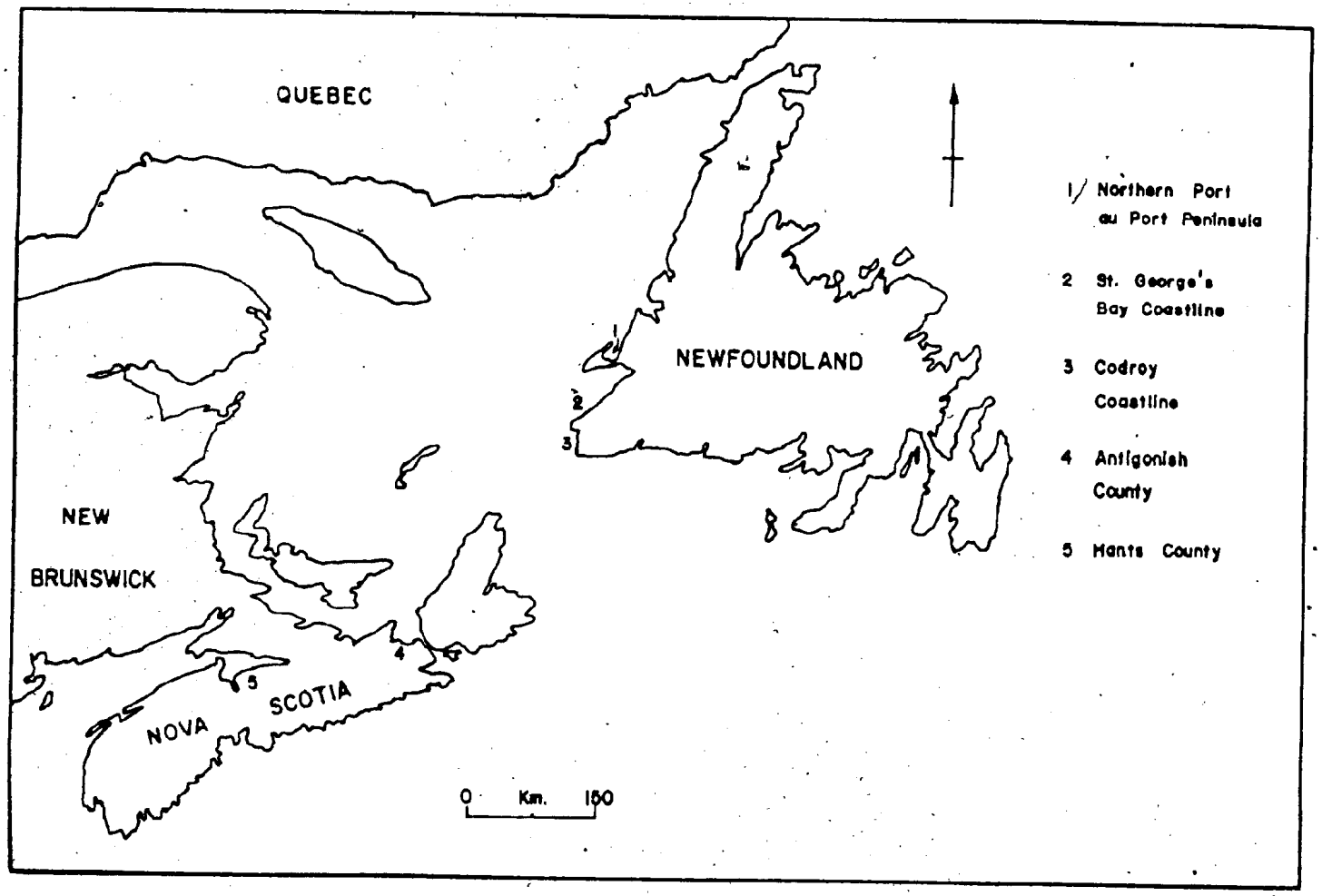
This is the first study of its kind to be undertaken in eastern Canada; earlier microfaunal studies having been restricted to foraminiferida and conodonts.

1.2 Geographical setting.

The study area is located in southwestern Newfoundland and northern and central Nova Scotia (Text-fig. 1.1). Being within the most easterly area of extensive, exposed Carboniferous strata in North America, the study area allows for close comparisons with Europe, Mid-Continental North America and North Africa. The geographical location of the study area is therefore critical for palaeogeographical correlations.

The study area affords good coastal and stream exposures. Access to the area is provided by the Trans-Canada

Text-figure 1.1 Location map of study area.


QUEBEC
NEWFOUNDLAND
NEW
BRUNSWICK
NOVA
SCOTIA
1
2
3
4
5
0 Km. 150
1/ Northern Port au Port Peninsula
2 St. George's Bay Coastline
3 Codroy Coastline
4 Antigonish County
5 Hants County

Highway and a network of secondary roads that lead to coastal and river exposures. All the sampling locations are easily accessible. In almost all cases where samples were collected the exposure is good to excellent.

1.3 Previous work.

1.3.1 Newfoundland lower Carboniferous geology.

Geological research involving the Carboniferous strata of Newfoundland was begun in the 19th century; however, little work was done prior to the 1930's. Advances made during the period 1934-1938 remained as the only major contributions until the late 1940's and early 1950's. However, it was not until the 1960's and later that the more detailed studies leading to the present level of understanding were undertaken.

The first major contribution to the understanding of Carboniferous geology in Newfoundland was made by Murray in 1873 (Murray and Howley 1881) wherein a fivefold division of the strata was presented. In southwestern Newfoundland Murray recognised a total sequence thickness of 9450 feet, of which he considered the lower 3450 feet to be the "Windsor Marine Series, with limestones of late Mississippian age". Murray recognised three divisions of the Windsor Series in southwestern Newfoundland:

> "Division C. Variegated red, green and dark coloured marls and sandstones that are often calcareous. Blue and grey limestones with the Windsor marine fauna. Very fragmentary plants in the sandstones. Salt springs frequent.....2000'
> Division B. Gypsum with green, black, brown and red shales and bands of black of dark grey limestones...150'
> Division A. Very coarse conglomerate with boulders of granite and limestone derived from the Long Range Mountains, cemented by a greenish sand. At the top,

this division passes into flaggy sandstone and greenish shale. Very variable in thickness and locally absent. Maximum.....1300'"

No further work was done until Schuchert and Dunbar (1934) described the main areas of Carboniferous deposition as being those of southern and western Newfoundland, i.e. from Codroy to the Port au Port Peninsula, Deer Lake in central Newfoundland, and north-central Newfoundland around White Bay and Cape Rouge (north of Canada Bay on the Northern Peninsula).

Later Hayes and Johnson (1938) subdivided the Carboniferous strata into the Barachois, Codroy and Anguille Series and gave formal descriptions of these series, as well as detailed sections of the St. George's Bay outcrops.

Bell (1948) described measured sections for the Carboniferous outcrop successions in the entire St. George's Bay area. These descriptions served as a basis for all further work.

Baird and Coté (1964) established the Anguille and Codroy Groups as lithostratigraphic units and correlated them with the Horton and Windsor Groups of Nova Scotia. Palynological investigations of the Codroy and Barachois Groups by Utting (1965) allowed for closer correlations with other Maritime strata of similar ages. These correlations were extended by Belt (1969) to include comparisons with the Carboniferous of Ireland.

In recent years the Carboniferous geology of the Deer Lake Basin has been studied in detail by Hyde (1979). Dix (1981) studied the depositional environments of the Codroy sediments on the Port au Port Peninsula.

Knight (1983) extensively remapped southwestern

Newfoundland and established a more detailed formational terminology than had previously existed.

1.3.2 Nova Scotia lower Carboniferous geology

Although research into Carboniferous strata was begun in the middle and late 1800's in Nova Scotia, the foundation that the early works laid was not built upon until the late 1920's. An intermittent series of significant papers ensured the progress of research through the period prior to 1960. Since 1960, however, heightened interest in the economic potential of Carboniferous sediments has resulted in a substantial increase in the number of workers actively publishing data.

The first major contributor to the understanding of Nova Scotia Carboniferous geology was J.W. Dawson. In one of his early works (Dawson, 1845) he recognised that the lower Carboniferous series could be differentiated into an upper Gypsiferous formation and a lower estuarine or lacustrine formation. In the first edition of "Acadian Geology" (Dawson, 1855) the Horton and Windsor Series were formally established. Hartt (1867) made the first investigations into the subdivisions of the Windsor Series on the basis of faunal content, and this information was the basis for the classification in the 2nd edition of "Acadian Geology" (Dawson, 1868), wherein eighty-seven different species were described from the Windsor Series, in agreement with the work of Hartt.

Bell (1929) erected a fivefold faunal subzone system for the Windsor Series and established a new succession for the various limestone units exposed in the type area from which the subzones were described. This order of limestones has become the most

generally accepted stratigraphic classification of the Windsor Series - a chronostratigraphic term.

	Dawson (1868)		Hartt (1867)		Bell (1929)
Upper Series	*Productus* Limestone	=	Stewiacke Limestone	=	Subzone B
	Aviculopecten Limestone	=	Windsor Limestone	=	Subzone B
	Zaphrentis Limestone	=	Kennetcook Limestone	=	Subzone E
Lower Series	Crinoidal Limestone	=	Oolitic fossiliferous Limestone	=	Subzone C
	Spirifer Limestone	=	Avon Limestone	=	Subzone D

From 1930 to 1960 Bell published a series of papers concerned more directly with fossil floras from the upper Carboniferous units and the Horton Group than with the Windsor Group (Bell, 1938, 1940, 1944, 1958, 1960). In 1944 Bell revised the Windsor Series to the Windsor Group, i.e. recognising it as a lithostratigraphic unit.

Stacey (1953) extended Bell's subzones from the type area to Cape Breton Island and Sage (1954), studying the Antigonish area, gave an indication of the effects facies variation could have on the fauna present in any given subzone.

The tectonic and environmental setting of the Maritime Carboniferous sediments has been widely studied since 1960. Roliff (1962), Belt (1964, 1965) and Kelley (1967) considered the Nova Scotian Carboniferous sedimentation in terms of sub-basins affected by tectonic activity resulting in rapid facies changes. Moore (1967)

and Schenk (1969) showed that the lithostratigraphic units of the Windsor Group represented repeated transgressive episodes. Schenk (1969, 1975), recognising the lateral facies changes and the time transgressive character of the units proposed an environmental model for the lower Windsorian Stage. Geldsetzer (1978), however, suggested a different environmental setting for the same strata, and this difference of opinion has not yet been fully resolved (see section 1.4.2). Recent work by Giles and co-workers of the Nova Scotia Department of Mines has culminated in a synthesis (Giles, 1981) involving five major transgressive-regressive cycles that affected a complicated basin structure. Giles (1981) further correlated these cycles with a similar series of cycles occurring in the United Kingdom (Ramsbottom, 1973, 1977, 1979).

An overview of previous work completed in both Newfoundland and Nova Scotia indicates that an understanding of the stratigraphic relationships of the Windsor and Codroy Groups has to be intimately connected with an understanding of the evolution of a complex tectonic environment.

1.3.3 Ostracoda.

Since the initial foundations were laid by T. R. Jones and J. W. Kirkby in the late 1800's, Carboniferous ostracode research has focussed on three main geographical regions, namely North America, Europe and Russia. Within these regions studies have for the most part been completed in restricted areas of importance. This has had the net result of giving a biased view of Carboniferous ostracode palaeobiogeography, both from regional and taxonomic perspectives.

The need for more studies outside these classical areas has only recently become recognised.

During the period 1865 to 1895, Jones and Kirkby described Carboniferous ostracodes from areas as far apart as Nova Scotia (Jones and Kirkby, 1884) and Mongolia (Jones and Kirkby, 1892), but their main body of research dealt with British and Irish faunas.

After the death of T. R. Jones in 1901, research in this field was essentially discontinued in Europe and Russia until the 1960's. During this time the only signifiant works from these areas were by Latham (1933) working on Scottish Carboniferous ostracodes; Kummerow (1939, 1953), studying German and Polish faunas; Batalina (1926), researching in the area of Novgorod, south of Leningrad; and Posner (1951) and Zanina (1956) publishing on the ostracodes of the Moscow basin.

There were few foundation studies in North America (Ulrich, 1891; Ulrich and Bassler, 1906,1908). However, during the late 1920's to the mid 1940's the focus of research moved to Mid-Continental North America where several important studies were completed. Two of the most important series of studies were by Croneis and his students studying the ostracodes of the Mississippian cyclothems in Illinois (Croneis and Gale, 1938; Croneis and Bristol, 1939; Croneis and Funkhouser, 1939; Croneis and Gutke, 1939; Croneis and Thurmann, 1939), and by Coryell and his students studying upper Carboniferous and Permian ostracodes of the Mid-Continental region, (Coryell, 1928a,b; Coryell and Brackmier, 1931; Coryell, and Billings, 1932; Coryell and Osorio, 1932; Coryell and Sample, 1932; Coryell and Booth, 1933; Coryell and Sohn, 1938; Coryell and Johnson, 1939; and Coryell and Rozanski, 1942). Other significant papers were

by Bradfield (1935), Delo (1930, 1931), Geis (1932), Harlton (1927, 1928, 1929a,b, 1933), Knight (1928), Morey (1935a,b, 1936), and Scott (1942, 1944). The major contributions to the understanding of North American faunas were, however, made in papers by Kellett (1933, 1934, 1935) focussing on the Pennsylvanian and Permian ostracodes of Kansas and Texas, and by Cooper (1941, 1946) studying the Carboniferous ostracodes of Illinois. Since most of these works represented new information featuring many new species, taxonomic synonymy has become a problem in recent years as type material is studied in the light of modern ideas about ostracode taxonomy.

From the late 1950's onward Carboniferous ostracode study became more cosmopolitan. In North America the most important contributions have been by Sohn in a series of papers, of which his revisions of the superfamily Paraparchitacea (1971), the family Amphissitidae (1961) and the genus *Bairdia* (1960) have been the most significant. In Europe the work of Grundel in the 1960's tended to focus on short stratigraphic intervals (Grundel 1961, 1962b, 1963) or on morphological and taxonomic problems (Grundel 1962a, 1965, 1966).

The most important works in Europe have been due to the efforts of Bless, Becker and Sanchez de Posada, working together and independently on faunas from the Dinant Basin of Belgium and Holland (Bless, 1967a; Becker and Bless, 1974) and the upper Carboniferous of the Asturias Mountains of Northern Spain (Bless, 1967b, 1968; Sanchez de Posada and Bless, 1971; Sanchez de Posada, 1977; Becker and Sanchez de Posada, 1977; and Becker, 1978). Bless and Jordan, (1971b, 1972) reclassified the Family Hollinellidae. In recent years the most significant single contribution has been the Carboniferous section of the stratigraphic guide to British Ostracoda

by Robinson (1979) though the inclusion of 38 new species in the section "that may be of stratigraphic significance" only serves to underline the need for further comprehensive research.

In Russia Gorak (1964, 1966, 1967), Tschigova (1959, 1967) and Bushmina (1968, 1970, 1975) have been the main contributors to the knowledge of Carboniferous ostracodes, working mainly in the Donetz Basin, on the Russian Platform and in Siberia.

Tschigova (1970, 1975) and Tschigova and Bless (1976) have begun work on the correlation of Russian and European faunas; however, much of this work is still unpublished.

The few works from outside of the classical areas since Jones and Kirkby have been reported since 1960. Faunas from Japan have been described by Ishizaki (1963, 1964, 1968) and from the Bonaparte Gulf of northern Australia by Jones (1974) A paper focussing on some Carboniferous ostracodes of Egypt was published by Omara and Gramann (1966) and another on ostracodes from the Himalayas was published by Jain et al. (1972). Very recently a paper concerning Carboniferous ostracodes from Libya has been published (Bless and Massa, 1982).

Canadian Carboniferous ostracode studies are very few and have been erratically published. The first references to ostracoda were in Dawson (1868, 1879) and by Jones and Kirkby (1884, 1889). These form the foundation studies. No further work was done until some more species of ostracodes were described by Bell in 1929. Since then the only other works to be completed on Canadian faunas have been by Copeland (1960) and Green (1963) studying the lower Carboniferous of Alberta, and Copeland (1957b) and Bell (1960) studying the Carboniferous of the Maritime region. In 1965, Utting, working on a palynological study at Memorial University reported

ostracodes from the Codroy Group of southwestern Newfoundland but his specimens were lost and his collecting horizons could not be located. In the last ten or fifteen years, Bless and Jordan (1971a) described a new beyrichiacean species from the Carboniferous of Nova Scotia and Copeland (1974) presented a summary of biostratigraphic zonations using Devonian and Mississippian ostracodes from Canada.

The classification of Carboniferous ostracodes, and of ostracodes in general is, at this time, a matter of debate. Several monographs served as the foundation for the production of the Ostracode volume of the Treatise on Invertebrate Palaeontology, Part Q, Arthropoda 3 (Moore, ed: 1961). Two of the most important monographs with respect to Palaeozoic ostracodes were those of Bassler and Kellett (1934) and Henningsmoen (1953). Recent work, however, has shown the need for a comprehensive review of the Treatise classification at all taxonomic levels.

The Treatise classification was already being questioned at a high taxonomic level during the 1960's, when Henningsmoen (1965) erected the new subdivisions Hollinomorpha and Beyrichiomorpha. This was followed by the work of Grundel (1969), who erected the new suborder Kirkbyocopina based on his earlier considerations of the superfamily Kirkbyacea Grundel (1965). Adamczak (1966, 1968) reviewed the status of the Kloedenellidae and reassigned this family from the Palaeocopida to the Platycopa. Grundel (1967) raised the Kloedenellidae to subordinal status within the order Platycopida, and the Bairdiacea and Cytheracea to subordinal rank within the Podocopida. The suborders Platycopina and Metacopina of the Podocopida have been raised to ordinal level by Bandel and Becker (1975) whereas other authors still maintain these groups at subordinal rank (i.e. Kesling

and Chilman, 1978; Pokorny,1978). Becker and Sanchez de Posada (1977) presented a classification fundamentally different from that of the Treatise, by including the ordinal and subordinal taxa that had been proposed since the publication of the Treatise (Moore, 1961).

Several ostracode classifications are in use by various authors therefore, making it very difficult to choose and use a consistent and generally accepted classification. It is unlikely that this state of affairs will alter until a new edition of the Treatise is published. This point is admirably illustrated by Lord and Malz (1981) in their treatment of the problems raised by the study of muscle scar patterns in Cytherellidae and Healdiidae by Kristan-Tollman (1977).

1.3.4 Peracarida.

Since only two genera of Peracarida are reported herein, a comprehensive outline of previous peracarid research is not given. Few peracarids have been described from Canada. Dawson (1877) was the first to describe peracarids from Canada, and they have received only cursory attention since then. Copeland (1957a,b) has presented the most detailed recent studies of the arthropod fauna of the Maritimes. The occurrence of a new genus in the Carboniferous strata of Newfoundland (Fong, 1972) and the description of a previously undescribed species from Canada by Dewey and Fahraeus (1982) are the only recent works available that focus directly upon Canadian Peracarida. The paucity of detailed studies from the Canadian Maritimes is in marked contrast to the literature for the Mid-Continental region of North America, (Brooks, 1962) Britain,

(Schram, 1979) and Russia (Schram, 1980). An account of the palaeozoogeography of Devonian to Triassic malacostracans (Schram, 1977) indicates a general lack of data available for large areas of the globe. Enough detailed information is available from those areas that have been described to suggest crustacean community structures (Schram, 1981a) that can be widely applied as faunas from new areas are described.

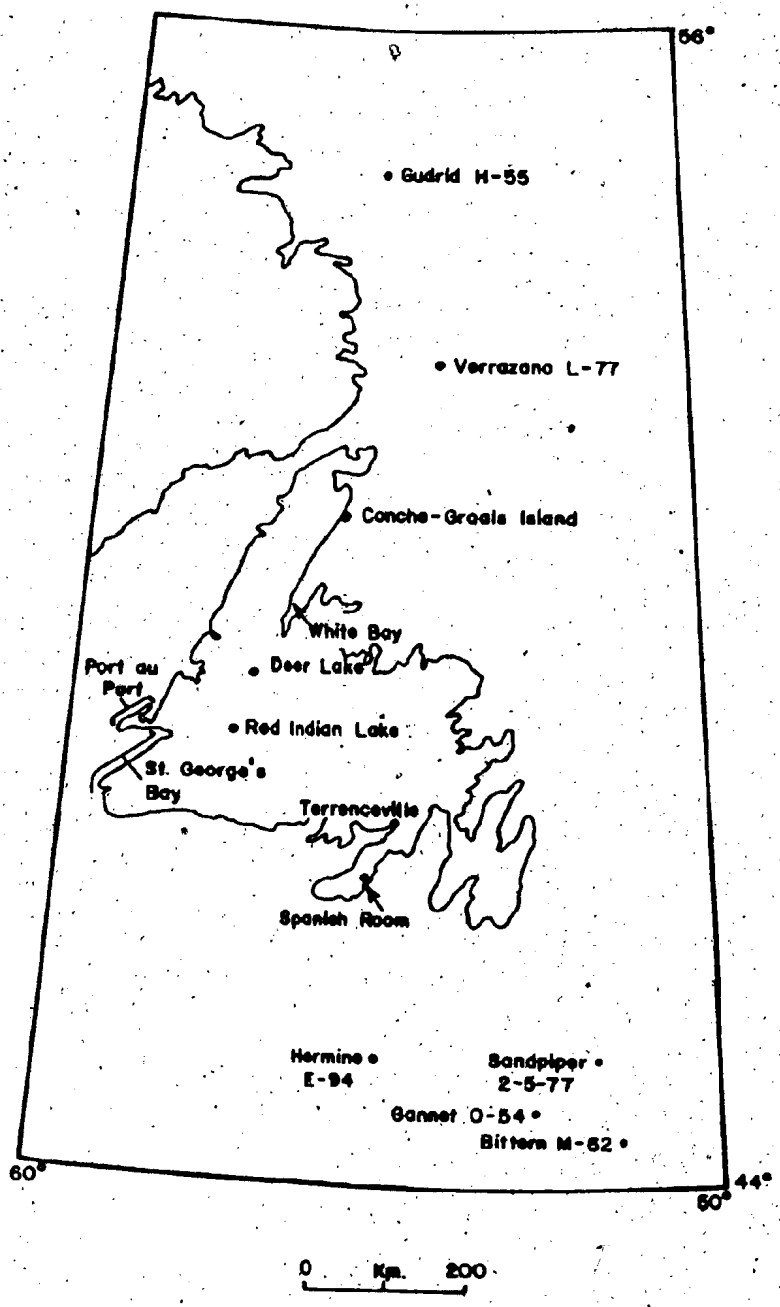
1.4 General geology.

1.4.1 Newfoundland Carboniferous geology.

The focus of the study is on the ostracodes from the middle Carboniferous Codroy Group sediments on the Port au Port Peninsula and in the St. George's Bay area of Newfoundland. There were, however, other areas where deposition of Carboniferous sediments took place, both on the island of Newfoundland and on the adjacent continental shelf. These areas include the Deer Lake - White Bay sub-basin (Hyde, 1979), the Conche-Groais Island area (Baird, 1966), the Red Indian Lake area (Belt, 1969) and small isolated areas on the Burin Peninsula (Howie and Barss, 1975; and Hiscott, pers. comm.). Published records of offshore deposits are found in Howie and Barss (1975) and Barss et al. (1979) (Text-fig. 1.2). Seismic studies and core samples suggest the presence of Carboniferous sediments on the continental shelf off White Bay (Jansa et al., 1978). The total known extent of offshore Carboniferous is shown in Sanford et al. (1979).

Most of these areas were subject to terrestrial sedimentation although marine sediments occur in the St. George's Bay sub-basin and in the offshore. However, an understanding of the

Text-figure 1.2 Map showing the main areas of exposed or drilled Carboniferous sediments in Newfoundland and the Continental Shelf.


56°
Gudrid H-55
Verrazano L-77
Conche-Groais Island
White Bay
Port au Port
Deer Lake
Red Indian Lake
St. George's Bay
Terrenceville
Spanish Room
Hermine E-94
Sandpiper 2-5-77
Gannet O-54
Bittern M-62
60°
50°
44°
0 Km. 200

relative distributions of all types of sediments is important for palaeobiogeographic and palaeoecological considerations.

Although the Carboniferous sediments of the St. George's Bay sub-basin are structurally complex, the area has been the focus of several major studies (Hayes and Johnson, 1938; Bell, 1948; Baird and Coté, 1964; Utting, 1965; Knight, 1983). This has in part been due to economic potential of coal and evaporite occurrences in these strata. The importance of the St. George's Bay sub-basin is enhanced by being the only area on insular Newfoundland with proven marine Carboniferous sediments.

The main Carboniferous stratigraphic units used in Newfoundland are summarised in Text-fig. 1.3 and have been defined in the St. George's Bay area.

In order to gain a clearer perspective of the significance of the Codroy Group in terms of its stratigraphy and palaeoenvironmental development on the St. George's Bay sub-basin, brief descriptions of the Anguille and Barachois Groups are given before a more detailed account of the Codroy Group.

The Anguille Group sediments are mostly immature greywackes and arkosic and feldspathic sandstones associated with dark grey, finely laminated, turbiditic siltstones and argillaceous limestones (Baird and Coté, 1964). The earliest sediments of the Kennels Brook Formation (Text-fig. 1.3) may be of Late Devonian age. They represent the initial phase of sedimentation within a pull-apart basin. The succeeding formations of the Anguille Group are of lower Carboniferous (Tournaisian) age and thought to represent deltaic infilling of a lacustrine basin (Knight, 1983).

Text-figure 1.3 Chart showing the development of stratigraphic classification for the Carboniferous strata of Newfoundland, from 1938 to 1983.

<table>
<tr><th>Hayes and Johnson 1938</th><th>Bell 1948</th><th colspan="2">Baird and Coté 1964</th><th colspan="2">Knight 1983</th></tr>
<tr><td rowspan="2">Barachois Series</td><td>Barachois Series</td><td colspan="2">Barachois Group</td><td colspan="2">Barachois Group</td></tr>
<tr><td>Searston Beds</td><td colspan="2">Searston Beds</td><td colspan="2">Searston Formation</td></tr>
<tr><td rowspan="2">Codroy Series</td><td rowspan="2">Codroy Series</td><td colspan="2">Upper Codroy Group</td><td rowspan="3">Codroy Group</td><td>Woody Cape Fm.
Robinsons River Fm.
Codroy Road Fm.</td></tr>
<tr><td colspan="2">Lower Codroy Group</td><td>Ship Cove Fm.</td></tr>
<tr><td>Anguille Series</td><td>Anguille Series</td><td>Anguille Group</td><td>Seacliffe Fm.
Snakes Bight Fm.
Cape John Fm.</td><td>Anguille Group</td><td>Spout Falls Fm.
Friars Cove Fm.
Snakes Bight Fm.
Kennels Brook Fm.</td></tr>
</table>

The upper Carboniferous Barachois Group has been of interest for its coal deposits (Hayes and Johnson, 1938). It consists of grey, red and green, rippled and cross-bedded gritty feldspathic sandstones and shales in fining upwards sequences. Knight (1983) has suggested that the Barachois Group sediments represent meandering river deposits associated with backswamp marshes. For more detailed accounts of the Anguille and Barachois Groups the reader is referred to Knight (1983).

Previous reports of Carboniferous ostracodes occurring in Newfoundland have been stratigraphically limited to the Codroy Group of the St. George's Bay sub-basin (Hayes and Johnson, 1938; Bell, 1948; Utting, 1965), therefore samples from the marine units of this sequence form the bulk of the collected material. Exhaustive sampling of all marine units in the Codroy Group has not been possible.

The stratigraphic subdivision and the palaeoenvironmental reconstructions of the Codroy Group established by Knight (1983) form the most comprehensive work compiled thus far and is therefore the main source of information with regard to the stratigraphy of the Codroy Group. However, this information was not available when the initial samples for this study were collected.

The middle Carboniferous Codroy Group (Knight, 1983), was subdivided into four formations (Text-fig. 1.3) and a brief synopsis of each formation, together with its palaeoenvironmental characteristics and main sampling horizons are now given.

The 20m. thick Ship Cove Formation is composed of grey argillaceous, algal and pelletal limestones and shales. In places where the Ship Cove Formation can be seen to overly the Anguille

Group, there is a sudden change from non-marine to marine conditions and Knight (1983) suggests the possibility of an interformational hiatus. The sediments of the Ship Cove Formation, which record the first Carboniferous marine incursion into the St. George's Bay sub-basin, are thought to represent a broad tidal flat, with subtidal conditions that prevailed longer in the northern than in the southern part of the sub-basin, (Knight, 1983). Evaporitic shales and algal-bryozoan-brachiopod biohermal limestones described from the northern shore of the Port au Port Peninsula (Johnson, 1954; Riley, 1962; Dix, 1981) indicate the presence of a shallow subtidal environment in the northern part of the sub-basin and are considered to be Ship Cove equivalents (von Bitter and Plint-Geberl, 1982).

Sampling horizons include the Ship Cove Limestone exposed in Fischells Brook and the evaporitic shales and biohermal limestones of the northern Port'au Port Peninsula.

Overlying the Ship Cove Formation is the 145-300m thick Codroy Road Formation. It consists of predominantly red siltstones and sandstones, varicoloured siltstones occurring with gypsum and anhydrite, and rare black limestones or dolostones, e.g. the Cormorant and Black Point Limestones of Bell (1948). These sediments have been interpreted to represent cyclic successions reflecting flooding, dessication and progradation of a marginal marine to alluvial plain environment (Knight, 1983). The evaporites are thought to be of sabkha type in the north of the sub-basin and to represent hypersaline lagoons in the southern part (Knight, 1983). Samples were only collected from the Cormorant and Black Point Limestones.

The Robinsons River Formation, thought to be in excess of 500m thick, is subdivided into four members (Knight, 1983). The lowermost member is the Jeffreys Village Member which consists of red and grey shales to sandstones and conglomerates intercalated with carbonates and evaporites, e.g. Crabbes/Jeffreys Limestone of Bell (1948) which occurs near the top of the member. The *Nodosinella* band of Bell (1948) is also a part of this member and occurs about 100m below the Crabbes/Jeffreys Limestone. The Highlands Member is a coarsening upward sequence of red siltstones, sandstones and conglomerates. The overlying Mollichignick Member is composed mostly of fine red and grey siltstones and micaceous and arkosic sandstones. The topmost unit is the Overfalls Brook Member which is composed of pink, red and brown massive and cross-bedded arkosic grits, sandstones and conglomerates. The Jeffreys Village and Highlands Members together record the progradation of fluvial conditions followed by evaporitic conditions and, finally, flood plain environments. The Mollichignick and Overfalls Brook Members represent alluvial and lacustrine deposits in the lower member and a wedge of arkosic alluvial sequences in the upper member. Samples from the Robinsons River Formation were collected from the Crabbes/Jeffreys Limestone and the *Nodosinella* band.

The 700m thick Woody Cape Formation in the southwestern part of the sub-basin is correlated with the upper part of the Robinsons River Formation. This formation consists of fine-grained grey to grey-green and blue to black mudstones, siltstones and shales. Intercalations of green mica-rich sandstone, minor red sandstones and shales, and thin-bedded black limestones occur sporadically throughout the sequence. The suggested palaeoenvironment is a delta that was

subjected to intermittent marine incursions (Knight, 1983). Samples collected from the Woody Cape Formation in Woody Cove and Capelin Cove are from marine horizons occurring within a predominantly fresh water sequence.

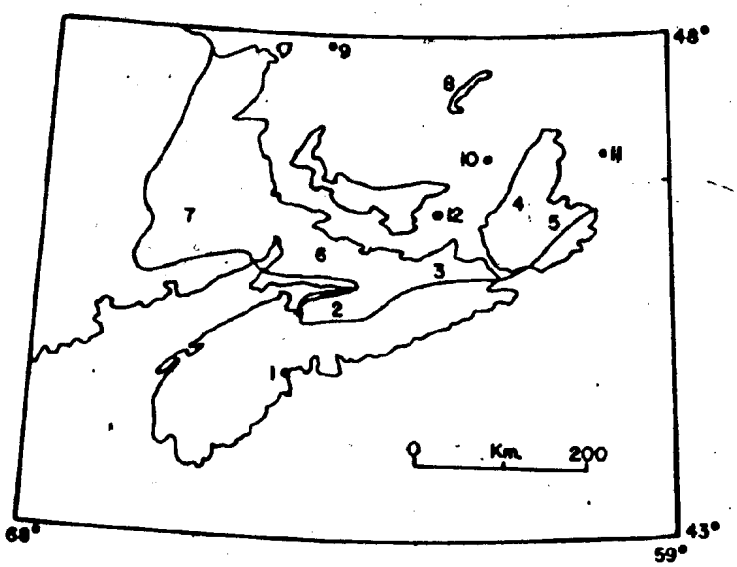
1.4.2 Nova Scotia Carboniferous geology.

The ostracodes collected from Newfoundland are augmented in this study by material collected from the middle Carboniferous Windsor Group sediments of the Antigonish and Minas sub-basins of Nova Scotia. Other areas of Carboniferous deposition in the Maritime region include the Cumberland, the Sydney and the Moncton sub-basins (Text-fig. 1.4) (Roliff, 1962; Kelley, 1967; Howie and Barss, 1975; Giles, 1981).

Wells located in the Gulf of St. Lawrence have also penetrated Carboniferous sediments, and records of these have been published in Barss et al. (1979). The total extent of offshore Carboniferous sediments is shown in Sanford et al. (1979).

Carboniferous sedimentation in the sub-basins of the Maritime region was neither continuous within, nor synchronous among the sub-basins (Roliff, 1962; Giles, 1981). This has hampered inter-sub-basinal correlations, since stratigraphic units established within one sub-basin may not easily be applied in another due to factors such as facies variations and periods of non-deposition.

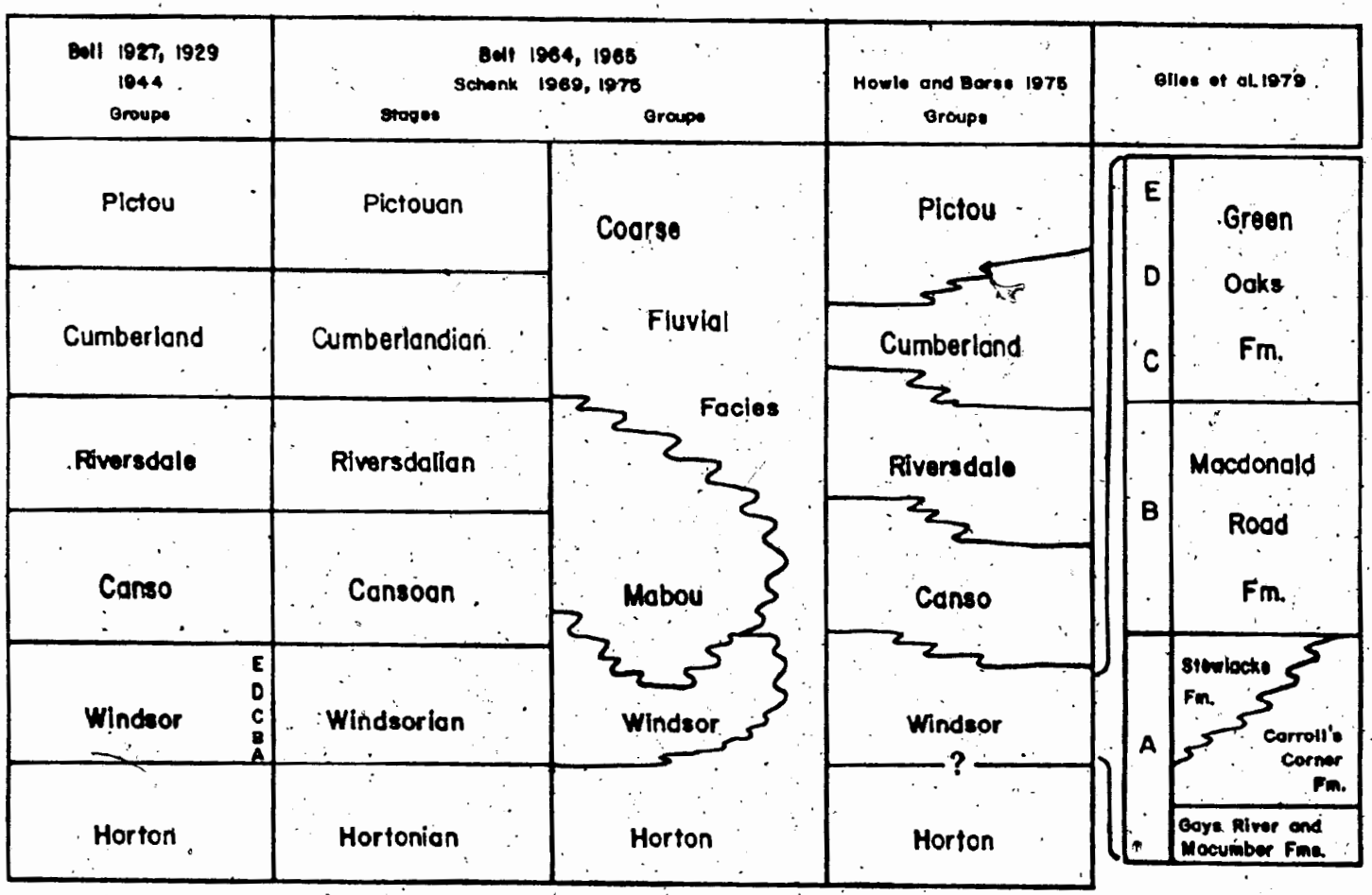
The major Carboniferous stratigraphic units recognised in Nova Scotia are summarised in Text-fig. 1.5. Since the ostracodes used in this study were collected only from the Windsor Group, a summary of the remaining Groups will now be given.



1 Mahone Bay
2 Minas
3 Antigonish
4 Mabou
5 Sydney
6 Cumberland
7 Moncton
8 Magdalen Islands
9 Bradelle L-49
10 East Point E-49
11 North Sydney P-05
12 HB Flna F-25

Text-figure 1.4 Map showing the main areas and extent of exposed and drilled Carboniferous sediments in the Maritime Provinces and the Gulf of St. Lawrence.

Text-figure 1.5 Chart showing the development of stratigraphic classification for the Carboniferous strata of Nova Scotia from 1927 to 1979.


Bell 1927, 1929
1944
Groups
Bell 1964, 1965
Schenk 1969, 1975
Stages
Groups
Howie and Barss 1975
Groups
Giles et al. 1979
Pictou
Pictouan
Coarse
Fluvial
Facies
Pictou
Cumberland
Cumberlandian
Cumberland
Riversdale
Riversdalian
Riversdale
Canso
Cansoan
Mabou
Canso
Windsor
E
D
C
B
A
Windsorian
Windsor
Windsor
?
Horton
Hortonian
Horton
Horton
E
D
C
Green
Oaks
Fm.
B
Macdonald
Road
Fm.
A
Stewiacke
Fm.
Carroll's
Corner
Fm.
Gays River and
Macumber Fms.

Sediments assigned to the Horton Group range in age from the upper Devonian (Eifelian) to the lower Carboniferous (Tournaisian to earliest Viséan) (Howie and Barss, 1975), and vary in thickness from less than 9m to more than 300m. The Horton Group sediments of the Minas sub-basin were described by Bell (1929, 1960). The lower sediments of the Horton Group are predominantly grey and brown feldspathic conglomerates, orthoquartzites and minor ferruginous limestones, occurring together with sandstones and shales that are often rippled or ribboned. The upper Horton Group sediments are predominantly red and green arkosic and micaceous sandstones and shales with occasional conglomerates (Bell, 1960; Howie and Barss, 1975). The Horton Group sediments are thought to represent alluvial fans and fluviolacustrine deposits (Roliff, 1962; Howie and Barss, 1975).

The upper Carboniferous sediments of the Maritime region are subdivided into four lithostratigraphic groups, the Canso, Riversdale, Cumberland and Pictou Groups. Sediments of the Canso and Riversdale Groups were first described from the Antigonish and Minas sub-basins by Bell (1944). According to Bell (1944) the Canso Group should be Namurian in age and the Riversdale Westphalian A in age. Diagnostic mega-fossils are, however, absent from the type locality of the Riversdale Group (Kelley, 1967; Howie and Barss, 1975); Kelley (1967), therefore, on the basis of palynological evidence, considered the Canso and Riversdale Groups at least in part contemporaneous. Howie and Barss (1975) suggest that the groups range from Viséan to Westphalian A in age, with a varying thickness from about 600m to more than 3000m.

The Canso Group is a sequence of non-marine red and

grey rippled, crossbedded and mudcracked shales, and sandstones overlying the marine Windsor Group sediments. The overlying Riversdale Group sediments are essentially similar in composition (Howie and Barss, 1975). The Canso and Riversdale sediments are thought to have been deposited in fluvial and fluviolacustrine environments and are in part equivalent to the Mabou Group established by Belt (1964).

The Cumberland and Pictou Groups are considered together because they are suggested to be in part contemporaneous (Howie and Barss, 1975). The Cumberland Group sediments range in age from Westphalian A to B with the Pictou Group sediments ranging in age from Westphalian B to lower Permian (Kelley, 1967; Howie and Barss, 1975; Hacquebard, 1980) and can attain a combined thickness of more than 3500m. The Cumberland Group sediments consist of red and grey conglomerates, shales and sandstones, occuring together with economically viable coal deposits. The type section of the Pictou Group along River John in the Cumberland sub-basin (Bell, 1944) is a sequence of red and minor grey sandstones, arkoses, shales and coals. The Morien Group in the Sydney sub-basin is equivalent to the Pictou Group but is in part older than the oldest sediments of the type section (Kelley, 1967). The Pictou Group sediments blanket almost the entire Maritime Basin (Roliff, 1962) and represent prograding fluvial and fluviolacustrine environments (Howie and Barss, 1975) and paralic basins in coastal lowlands (Hacquebard, 1980). These sediments have been considered to be part of the Coarse Fluvial Facies established by Belt (1964). (See Text-fig. 1.5)

The only proven marine deposits in the Carboniferous succession of the Maritime Basin occur in the +1000m thick middle

Carboniferous Windsor deposits. The Windsor Group sediments were subdivided on the basis of their megafaunal content into five faunal zones, first defined in the Minas sub-basin by Bell (1929). The faunal elements do, however, have distinct facies relations (Schenk, 1967), although the zones have been successfully applied beyond the Minas sub-basin according to Stacey (1954), Sage (1959), and Moore and Ryan (1976). The problem of middle Carboniferous correlation both within the Windsor Group itself and on a world-wide basis will be considered in the section 1.4.4 however the subdivisions recognised in the Shubenacadie area of the Minas sub-basin are used when describing the Windsor Group lithologies since they have been correlated most closely with the faunal zones of Bell (1929) by Giles et al. (1979) and Giles (1981).

The lowermost units of the Windsor Group are the Gays River and Macumber Formations, which form the base of Faunal Zone A (Text-fig. 1.5) and record the initial transgressive phase in the Maritime Basin.

The 3 to 20m thick Macumber Formation consists of laminated and pelletoidal grey limestones that have been recorded widely in the Maritime region (Bell, 1929; Stacey, 1953; Sage, 1954; Neale and Kelley, 1960; Schenk, 1967, 1975; Geldsetzer, 1977, 1978; Giles, 1981). The limestones are micritic, normally unfossiliferous and sometimes moldic after evaporite crystals. The Gays River Formation, which consists of locally very fossiliferous micritic algal-bryozoan-brachiopod mounds is thought to be laterally equivalent to the Macumber Formation. A sample equated with the Gays River Formation (Geldsetzer et al., 1980) was collected from the limestone in Calpo Quarry,

Antigonish sub-basin.

The Macumber and Gays River Formations are overlain by the 350m thick Carrolls Corner Formation which is correlated with the upper part of Faunal Zone A. This formation consists mostly of anhydrite and gypsum with thin intercalations of limestone, dolostone and red siltstones, and shales (Sage, 1954; Giles, 1981). It is overlain by the 300m thick Stewiacke Formation. The main rock type of the Stewiacke Formation is halite with minor anhydrite and siltstones. In the Shubenacadie area it is the topmost formation of Faunal Zone A (Giles, 1981).

The Macdonald Road Formation is equated with Faunal Zone B (Giles et al., 1979). The lithologies of this formation include a rhythmic series of gypsum and anhydrite (which may predominate), carbonates and red and brown, fine grained, siliciclastics (Giles, 1981). There are only two main carbonate units in this formation, namely the Miller and Maxner Limestones, however, due to the faulted nature of the type section, Bell (1929) was uncertain as to their stratigraphic relations. Geldsetzer et al. (1980) have suggested that the Miller Limestone is the younger of the two. There are several other thin limestone units occuring within equivalents of the Macdonald Road Formation and samples were collected from the Dimrock and Phillips limestones of the Wentworth Formation that equates with the upper part of the Macdonald Road Formation in the western part of the Minas sub-basin (Geldsetzer et al. 1980). Due to both diapiric movement and depositional variation evaporite thicknesses of the formation vary from a few metres to almost 400m.

Faunal Zones C, D and E are equated with the 185 to

300m thick Green Oaks Formation (Giles et al., 1979). This formation is composed mostly of red and brown siltstones and sandstones intercalated with minor limestones; evaporites are typically absent. A detailed account of the seven main limestone units occurring in this formation was published by Moore (1967). Only one sample was collected from sediments that are correlatable with the Green Oaks Formation and that was from the Kennetcook Limestone which, according to Moore (1967), equates with Faunal Zone E.

Palaeoenvironmental analysis of the Windsor Group sediments has been a matter of much debate (Schenk, 1969, 1975; Geldsetzer, 1977, 1978; Giles, 1981). However, it is generally agreed that the sediments indicate that the Maritime Basin was subject to intermittent transgressive episodes. Schenk (1969, 1975) suggests that the Macumber-type limestones reflect intertidal and shallow lagoonal sediments deposited basinward of supratidal salt flats and continental alluvial fans. Sediments of the Gays River-type are suggested to have been deposited in a basinward position with regard to the Macumber-type. This interpretation is fundamentally different from that of Geldsetzer (1977, 1978) who suggests that the Gays River-type bioherms were built upon basement highs in a subtidal environment and that the Macumber-type lithologies reflect deposition in a subtidal environment away from the basement highs, this interpretation has been supported by Giles et al. (1979) but is not yet fully resolved.

It is clear from faunal evidence that the initial transgressive episode was not of normal salinity and Geldsetzer (1977, 1978) suggests that the evaporite deposits occurring

stratigraphically above the Gays River and Macumber Formations formed by stagnation and evaporation of the transgressive sea, as opposed to the supratidal salt flat theory of Schenk (1969, 1975). The sediments indicate that several transgressive-regressive cycles occurred during the deposition of the Windsor Group (Moore, 1967; Howie and Barss, 1975). Giles (1981) has delineated five major transgressive-regressive cycles, but only the first major cycle was formed by a single transgressive-regressive episode, the remaining major cycles consist of several minor cycles. Giles (1981) also states that the later carbonates of the Green Oaks Formation were more nearly marine than those of the Macumber and Gays River Formations.

The stratigraphic significance of the major transgressive-regressive cycles will be discussed in section 1.4.4, after an evaluation of the tectonic environment that controlled the sedimentation.

1.4.3 Regional tectonic framework.

In order to establish palaeobiogeographic reconstructions (Chapter 5) it is important to understand the tectonic framework of the Maritime Basin and its development.

Deposition of Carboniferous sediments in the Maritime Basin (or the Fundy Epieugeosyncline of Howie and Barss (1975)) was a function of the tectonic environment that produced pull-apart basins on the margin of the Appalachian orogen during the Devonian and the Carboniferous (Bradley, 1982).

Since Wilson (1966) suggested that the Proto-Atlantic (Iapetus) Ocean closed during the Palaeozoic and the present Atlantic

Ocean opened during the Mesozoic, a large number of papers have been written on the tectonic history of the Palaeozoic Appalachian/Caledonian Orogeny. It is clear that previous models of the Orogen (Williams, 1964, 1979; Dewey, 1969; Bird and Dewey, 1970; Wright, 1977) are not entirely satisfactory for explaining the late Palaeozoic tectonic framework of the Maritime region and as new models are developed (Williams and Hatcher, 1982: Keppie, in press) large-scale strike-slip motions, "suspect terraines" and the influence of the Hercynian Orogeny are becoming recognised as important factors in the late Palaeozoic development of the Appalachian/Caledonian Orogen.

Until very recently the generally accepted model of the Appalachian Orogeny was that of a symmetrical orogen that could be subdivided into at least five major tectono-stratigraphic zones (Williams, 1978, 1979). This model suggests that these zones, across the orogen are as follows, from west to east:

1. The Humber Zone representing the old continental margin of eastern North America.

2. The Dunnage Zone representing vestiges of the consumed Iapetus Ocean.

3. The Gander Zone representing the eastern margin of the Iapetus.

4. The Avalon Zone paralleling the Humber Zone along most of the orogen, outboard of the Gander Zone.

5. The Meguma Zone which has been suggested to be a continental embankment of North Africa.

According to this model these zones existed as physiographic features until the late Ordovicean, and it was suggested

that the middle to late Ordovician Taconic Orogeny marked the closure of the Iapetus and the destruction of its continental margins.

Very recently, however, studies by Williams and Hatcher (1982) and Keppie (in press) indicate that the orogen was not symmetrical and that a collage of "suspect terraines" have been accreted outboard of the North American geocline. Although the details of this model have yet to be fully evaluated, it allows for greater tectonic flexibility outboard of the orogen. The concept of accretion of terraines to North America at different stages allows for a clearer understanding of the roles played by the Acadian and Alleghenian orogenic episodes, and also allows for a closer correlation with the Hercynian orogen of Europe.

Burrett and Griffiths (1977) and Johnson (1973) suggest that the Caledonian/Appalachian Orogeny resulted on the destruction of the Iapetus Ocean and that the Hercynian Orogeny in Europe, southeastern United States and North Africa closed a Hercynian Ocean (though not all authors agree with a mid European Hercynian Ocean i.e. Krebs and Wachendorf, 1973). This concept agrees with that of Keppie (1982, and in press) who suggests that large-scale strike-slip motions of Carboniferous times occurred prior to the Alleghenian and Hercynian Orogenic episodes which resulted from the collision of Gondwanaland and Laurasia.

It is clear the the strike-slip movements are important in the development of the orogen, both prior to and during the collision of Gondwanaland and Laurasia, however the sense of these motions is at present unclear. Large-scale dextral strike-slip movements have been suggested to be responsible for the Hercynian closure (Leeder, 1976;

Arthaud and Matte, 1977); whereas sinistral strike-slip movement is thought to be responsible for the accretion of the Acadian Composite Terraine to North America (Keppie, in press) and a combination of sinistral and dextral movements has been suggested for the complete suturing of Gondwanaland and Laurasia (Lefort and Van der Voo, 1981; Ziegler, 1981).

Bradley (1982) and Keppie (1982) suggest that during the late Devonian to middle Carboniferous the Maritime Basin formed from a series of pull-apart structures formed dominantly by dextral strike-slip faulting. Knight (1983) further suggested that dextral displacements in the St. George's Bay sub-basin of southwestern Newfoundland during the middle Devonian to middle Carboniferous were responsible for the formation of the pull-apart basins in which the lower Carboniferous sediments were deposited. This is in accordance with the major dextral movements suggested by Arthaud and Matte (1977), for the Hercynian closure.

1.4.4 Stratigraphic correlation.

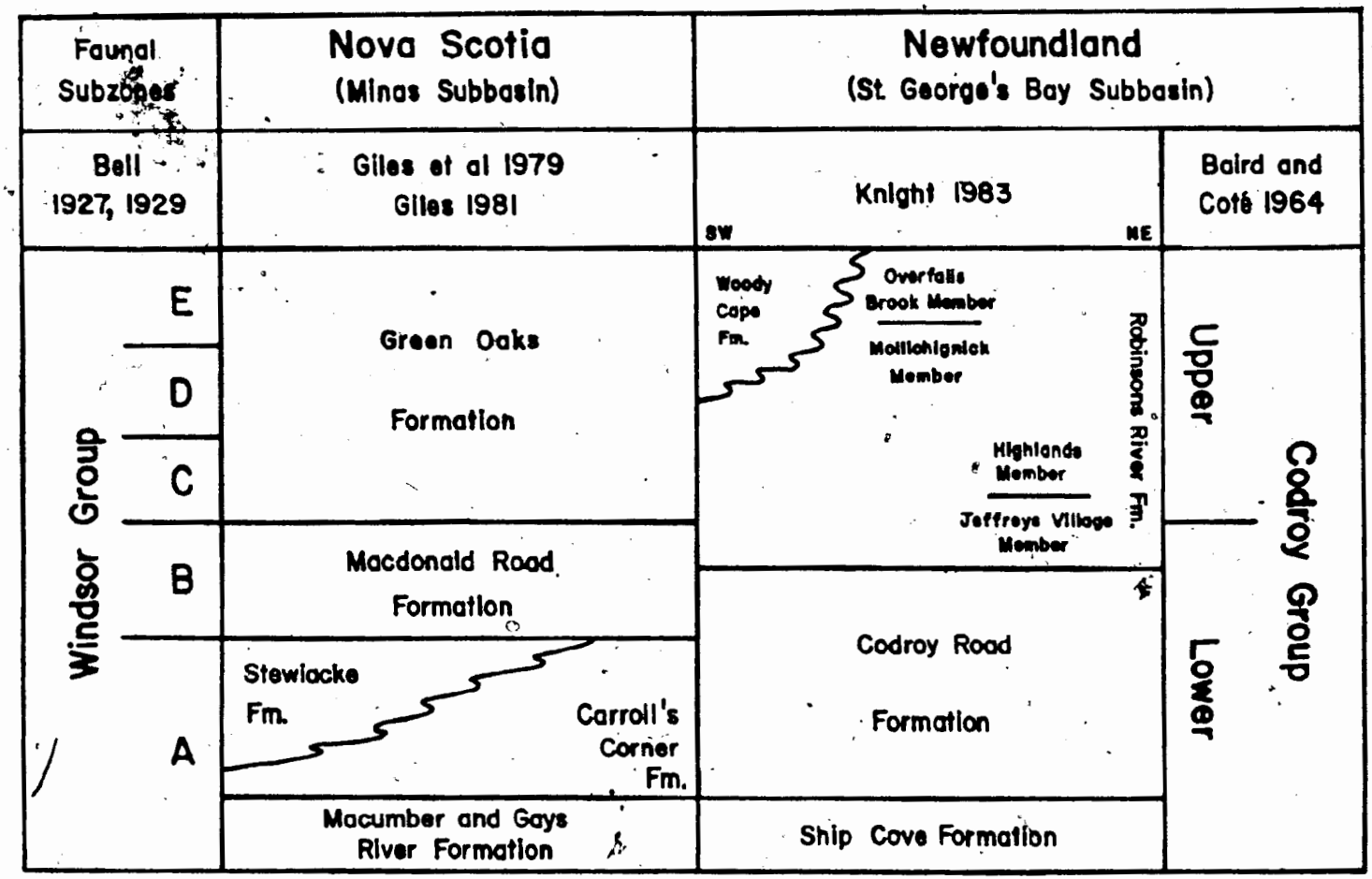
Although this study does not focus on stratigraphic problems, it is necessary to correlate the Carboniferous deposits of the Maritime Basin with other areas of Carboniferous sedimentation, if taxonomic and palaeobiogeographic discussions and conclusions are to have any relevance. Firstly the correlation of Nova Scotia and Newfoundland strata will be discussed, followed by a consideration of the more global aspects of correlation.

The Codroy and Windsor Group sediments of the Maritime Basin have been considered as lateral correlatives of one another by

several authors (Hayes and Johnson, 1938; Bell, 1948; Baird and Coté, 1964; von Bitter and Plint-Geberl, 1982; Knight, 1983). Correlation has been possible using the megafaunal subzones established by Bell (1927, 1929) and more recently by the use of conodonts (von Bitter and Plint-Geberl 1982) as well as by the more traditional lithostratigraphic similarities of the two groups. Recently, however, more detailed work both in Newfoundland and Nova Scotia has resulted in the construction of many new formational terms that have only limited applications within individual sub-basins of the Maritime Basin (Giles et al., 1979; Giles, 1981; Knight, 1983). These have in turn led to a better understanding of the sub-basinal variations in terms of lithology, stratigraphic continuity and the timing of stratigraphically important events within the sub-basins. A correlation chart (Text-fig. 1.6), adapted from Knight (1983), is used to show the stratigraphic relationships of the St. George's Bay sub-basin of Newfoundland and the Minas sub-basin of Nova Scotia both in terms of the more recent formation names and the more familiar faunal subzones of Bell (1927, 1929) and lower and upper Codroy Group of Baird and Coté (1964). This traditional nomenclature is also maintained for more global correlation since the formation names are only of limited use within the Maritime Basin.

The approximate chrono-stratigraphic relationships of the Carboniferous strata of eastern Canada with strata of an equivalent age in other areas of the world are summarised in Text-fig. 1.7. The correlations used herein are based on several sources (Mamet, 1970; Ramsbottom, 1973; Conil et al., 1976, 1979; George et al., 1976; Aisenverg et al., 1979; Dutro et al., 1979; Rotai, 1979; Giles, 1981;

Text-figure 1.6 Chart showing correlation of middle Carboniferous stratigraphic units from Nova Scotia and Newfoundland.


Faunal Subzones
Nova Scotia (Minas Subbasin)
Newfoundland (St. George's Bay Subbasin)
Bell 1927, 1929
Giles et al 1979
Giles 1981
Knight 1983
SW
NE
Baird and Coté 1964
Windsor Group
E
D
C
B
A
Green Oaks Formation
Macdonald Road Formation
Stewiacke Fm.
Carroll's Corner Fm.
Macumber and Gays River Formation
Woody Cape Fm.
Overfalls Brook Member
Mollichignick Member
Highlands Member
Jeffreys Village Member
Robinsons River Fm.
Codroy Road Formation
Ship Cove Formation
Upper
Lower
Codroy Group

Higgins, 1981; Utting, 1980, von Bitter and Plint-Geberl, 1982).

There are currently three major chronostratigraphic classifications of the Carboniferous period, namely the North American, the western European and the unified Russian classifications. It is into the framework formed by the interrelationships of these schemes that the Windsor and Codroy Groups of eastern Canada are fitted.

One of the first problems to examine in lower Carboniferous stratigraphy is the correlation of the Mississippian System used in North America and the Dinantian Subsystem used in western Europe. For the purposes of this study the Mississippian/ Pennsylvanian boundary is thought to occur at the top of the Chesterian Series of North America and within the lower Namurian Series of western Europe, (George et al., 1976; Dutro et al., 1979; Rotai, 1979; Higgins, 1981). Thus, while the terms Mississippian and Dinantian or lower Carboniferous may be used interchangeably for different ostracode occurrences, it should be remembered that the youngest Dinantian strata in Europe are older than the youngest Mississippian strata in North America. Since this study is only concerned with strata equivalent in age to the Visean and not the Tournaisian Series, the Devonian/Carboniferous boundary is not considered in relation to the Devonian/ Mississippian boundary.

Detailed stratigraphic subdivisions of lower Carboniferous sediments have been based upon several biostratigraphic markers including foraminiferida, conodonts, palynomorphs and a variety of mega-fossils. Few, if any, of the classifications established agree totally and only the foraminiferal zonation of Mamet (1970) and Mamet and Skipp (1971) has been applied in all three

major stratigraphic schemes (Text-fig. 1.7 in back pocket).

The correlation of Russian and western European chrono-stratigraphic units are after Conil et al. (1976) and Aisenverg et al. (1979). These schemes, however, are not in total agreement with regard to the position of the Tulsky/Alexinsky boundary. It is beyond the scope of this study to examine this argument, however, the conclusion proposed by Conil et al. (1976) is used because it deals in greater detail with more geographical areas.

The correlation of western Europe and North America follows Conil et al. (1976), George et al. (1976) and Dutro et al. (1979). Conil et al. (1976) is more detailed in regional analysis and therefore the position of the Tournaisian/Viséan boundary, with regard to the Keokuk Limestone, is placed according to Conil et al. (1976). They consider the Keokuk to be equivalent to the Chadian stage of the United Kingdom and therefore within the Viséan; a view also held by George et al. (1976) and Utting (1980). It should be noted that this is at variance with Dutro et al. (1979) and Rotai (1979) who place the Osagean Series of North America entirely within the Tournaisian.

These correlations form the framework into which the stratigraphic units of the eastern Canadian Carboniferous are fitted; a discussion of which now follows. The first correlation of Windsor Group sediments with similar strata in Europe was by Bell (1929) who assigned the major faunal zones A to E of the Windsor Group to the S2 to D2 major faunal zones of current usage in England. Mamet (1970) then correlated the Windsor Group sediments on the basis of foraminiferal zones 14 to 17 with the late Viséan (V3a to V3c) and

lowest Namurian (E) of Belgium and England. More recently Utting (1980) established three palynological assemblage zones for the Windsor Group sediments which he then correlated with the Arundian, Holkerian and Brigantian Stages of western Europe and lower Meramecian and lower Chesterian Series of North America. These correlations have all been examined by Giles (1981) in his discussion of Carboniferous transgressive-regressive cycles.

Giles (1981) considers the Windsor Group strata indicative of several transgressive-regressive cycles which he correlates with the British and American zonal schemes on the basis of foraminifers, conodonts, mega-fossils and palynomorphs. A detailed discussion of these correlations is given in Giles (1981), to which the reader is referred. One of the major points of interest to arise from this study, however, is the possible occurrence of a hiatus between cycles 2 and 3 of Giles (1981). The presence of this hiatus is tentative because the relative positions of the top of cycle 2 and the base of cycle 3 are not known with certainty, due to inconsistencies between the foraminiferal evidence of Mamet (1970) and the palynological evidence of Utting (1980).

The presence of transgressive-regressive cycles in Maritime Canada (Giles, 1981) follows the work of Ramsbottom (1973, 1979) who described similar cycles from the Carboniferous strata of England and Belgium. The relative ages of the cycles shown on Text-fig: 1.7 are after Ramsbottom (1973), George et al. (1976) and Giles (1981). The position of the cycles indicates that the groups of minor cycles that form a major cycle occur earlier in Belgium and Nova Scotia than they do in England (Giles, 1981) and this may be

related to the different tectonic environments. Precise correlations of these major and minor cycles with existing stratigraphic zonations requires more detailed studies.

1.5 Summary.

The marine middle Carboniferous sediments of Newfoundland and Nova Scotia were deposited during the middle to late Visean within a series of pull-apart basins that formed the Maritime Basin of eastern Canada. The pull-apart basins were part of a tectonic framework which included significant amounts of strike-slip movements. The faulting occurred as a result of the final phases of the Appalachian/Caledonian Orogeny and prior to the closing of a Hercynian Ocean between Laurasia and Gondwanaland.

The sediments deposited within the Maritime Basin vary from fluvial and fluvio-lacustrine siliciclastics to marine limestones, shales and evaporites. They record a series of transgressive-regressive cycles that can be correlated with similar episodes occurring in western Europe. In the succeeding chapters the palaeoecological and palaeogeographic significance of these cycles will be discussed in terms of their ostracode faunas.

CHAPTER 2

LOCALITY DESCRIPTIONS

2.1 Introduction.

The study area comprises a series of collecting localities in southwestern Newfoundland and northern and central Nova Scotia (Text-fig. 2.1 in back pocket). The localities were chosen on the basis of accessibility, stratigraphic continuity and the likelihood of yielding ostracodes from as many differing palaeoenvironments as possible. The Newfoundland samples were primarily collected from localities where marine units have been stratigraphically documented in the literature. However, at other localities the sampling intervals can be laterally correlated with such documented units. In Nova Scotia the collecting localities were controlled by the itinerary of the Geological Association of Canada Field Trip 22 (Geldsetzer et al., 1980). Samples from Nova Scotia therefore represent material taken from isolated horizons which were considered to be probable candidates for yielding ostracodes. The original intention was to use these samples as comparative material, however, the better preservation of the Nova Scotia material, coupled with the differing faunas collected from these localities led to their inclusion in the main body of the thesis.

2.2 Newfoundland.

The Newfoundland samples were taken primarily from lateral equivalents of the Ship Cove Formation and the Crabbes/Jeffreys Limestone and the *Nodosinella* Band of the Robinsons River Formation. These samples were augmented by material from marine bands of the

Woody Cape Formation (Text-fig. 1.6).

Stratigraphic notes include the more familiar lower and upper Codroy Group (Baird and Coté, 1964) and also the more recent terminology of Knight (1983). The reader is referred to Text-fig. 1.6 for correlation purposes.

The localities are situated on the northern shore of the Port au Port Peninsula, along the west coast of Newfoundland from Fischells Brook to the mouth of Crabbes River and in the Codroy Valley at Capelin Cove and Woody Cove (Text-fig. 2.1) and will be discussed in that order.

2.2.1 Northern shore on the Port au Port Peninsula.

All samples taken from this area are from lateral equivalents of the Ship Cove Formation (Text-fig. 1.6).

1. Mistaken Cove.

Locality: Mistaken Cove is situated at the end of an unpaved track, the turnoff to which is about 300m from Aguathuna Church and before the Felix Cove Community Office (Text-fig. 2.1). The sampling horizon is situated at the northern end of the east wall, at the first ledge of grey Ordovician limestone. The horizon is about 70cm above the ledge, in a black shale unit that varies in thickness intermittently from 5cm to 35cm (Text-fig. 2.2) (Dix, 1981, Section H, fig. 29).

Sample: Mi. 1.

Lithology: Finely bedded, hard, black calcareous shale with subangular quartz grains. Average grain size less than 63 mμ

Text-fig. 2.2 A

Text-fig. 2.2

A : View of the eastern side of Mistaken Cove showing sample locality.

B : Close-up of sample horizon showing irregular nature of unit.

C : Close-up of sample position.

Text-fig. 2.2 B

Mi. 1

Text-fig. 2.2 C

Mi. 1

Associated Lithologies: The sample horizon overlies, and is overlain by very fossiliferous micritic limestone containing brachiopods, bivalves and ?worm tubes.

Ostracode fauna: *Chamishaella suborbiculata*

Shemonaella scotoburdigalensis

Youngiella sp..

"Neokloedenella" variolata

bairdiocypridid gen. et sp. indet. 2

Healdia sp.?

Bairdia sp. L.

2. Aquathuna Quarry.

Locality: The sampling locality is situated on the north side of Lundrigan's Aguathuna Quarry operations, at the north end of the east wall excavations, about 75m from the power house (Text-fig. 2.1). The sample was taken to the left of the limestone block (Text-fig. 2.3) and consists of *in situ* limestone and weathered talus (Dix, 1981, section F, fig. 29).

Sample: Ag. Qu. 1

Lithology: Massive, very fossiliferous, buff coloured, rubbly, micritic limestone containing brachiopods, gastropods, bivalves, conularids, and bryozoans in roundish mounds about 1m in diameter.

Ostracode fauna: amphissitid gen. et sp. nov.

Youngiella sp.

Bairdia sp. L.

Acutiangulata n. sp. A.

Bassilerella firma

Text-fig. 2.3 A

Text-fig. 2.3 B

Text-fig. 2.3

A : View of the eastern wall of Aguathuna Quarry.

B : Close-up of sampling locality.
Telegraph pole for scale.

bairdiocypridid gen. et sp. indet. 2

Chamishaella suborbiculata

Shishaella moreyi

Polycope n. sp. A.

3. Aquathuna Brook.

Locality: On the south side of the main road less than ½km west of the power house is an unpaved track that runs alongside a minor brook. About 750m along the path is a dammed pond. Some 40m downstream of the pond is a poorly exposed sequence of calcareous sandstones and shales (Section A, Text-fig. 2.1)

Samples: Ag. Bk. 1

Ag. Bk. 2

Ag. Bk. 3 (barren)

Lithology: Samples Ag. Bk. 1 and 2 are taken from plant bearing, gritty calcareous sandstones. The calcareous sandstones contain plant debris and other fossil fragments, white mica flakes, orthoclase and quartz. Ag. Bk. 3 was taken from poorly lithified very dark brown, fine-grained shales which have some white mica and is rich in megaspores and plant fragments.

Crustacean fauna: *Acratia acuta*

Bassilerella firma

Shemonaella scotoburdigalensis

Chamishaella suborbiculata

Shishaella moreyi

Bellocaris newfoundlandensis

Tealliocaris sp. aff. *T. loudonensis*

4. Aquathuna "Island".

Locality: On the south side of the main road about 1km from the power house is an isolated oblong erosional remnant on the quarry floor, (Text-fig. 2.1, 1.4) the south and west walls of this "island" constitute the main locality for the Aquathuna samples. (Dix, 1982, section E, fig. 29).

Samples: Ag. 1

Ag. 2

Ag. 3

Ag. 4

Ag. 5

Ag. 6

Lithology: Ag. 1, Ag. 3 and Ag. 6 are taken from minor shale bands (Text fig. 2.4) within the limestones that constitute the major lithology of this outcrop. The shale from Ag. 3 contains rounded fragments of granite that range up to 240mm however the average grain size of both samples is less than 63mm. Ag. 2, Ag. 4 and Ag. 5 (Text-fig. 2.4) were collected from the yellowish brown, rubbly, bioclastic limestone. Associated fossils include brachiopods, spirorbis, gastropods, bivalves, conularids, bryozoans, algae and ?worm tubes. There is much secondary remobilisation of calcite evidenced by regrowth of calcite crystals within cavities. Secondary minerals occurring in the limestone include galena, sphalerite, marcasite and baryte.

Crustacean fauna: *Aechmina* sp.?

amphissitid gen. et sp. nov.

Youngiella sp.

Bairdia sp. L.

Text-fig. 2.4 A

Text-fig. 2.4

A : View of Aguathuna "Island" taken from the southwest.

B : View of the western side of Aguathuna "Island" showing sample positions.

C : View of southwestern end of Aguathuna "Island" showing sample positions.

Text-fig. 2.4 B

Text-fig. 2.4 C

Acratia acuta

Acutiangulata n. sp. A.

Monoceratina antiqua

Basslerella firma

Basslerella obesa

"Neokloedenella" variolata

Healdia sp.?

bairdiocypridid gen. et sp. indet. 2

Paraparchites sp. aff. *P. kellettae*

Shemonaella scotoburdigalensis

Chamishaella suborbiculata

Chamishaella n. sp. A.

Shishaella moreyi

Shivaella sp.

Polycope n. sp. A.

ostracode gen. et sp. indet. 3

Bellocaris newfoundlandensis

Tealloicaris sp. aff. *T. loudonensis*

5. Gillams Cove.

Locality: About 750m west of the Aguathuna "Island" locality, at the rise and bend in the highway is a small cove on the north side of the road (Text-fig. 2.1). The sample horizon is situated on the east side of the cove about 1m above the grey Ordovician limestones (Text-fig. 2.5) (Dix, 1981, section D, fig. 29).

Sample: GC. 1

Lithology: Yellowish brown, rubbly micritic limestone containing

Text-fig. 2.5 A

Text-fig. 2.5 B

Text-fig. 2.5

A : View of the east wall of Gillams Cove.

B : Close-up of sampling horizon.

brachiopods, bivalves, gastropods and worm tubes.

Peracarid fauna: *Bellocaris newfoundlandensis*

6. Boswarlos Beach.

Locality: Boswarlos beach is situated about 6km west of Gillams Cove. Along the north side of an unpaved road which joins the main road from the east, north of Boswarlos village, is the almost 8m thick Boswarlos cliff section (Text-fig. 2.1). Samples were collected from two sections in the sequence at this locality.

Samples: B. 1

B. 2

B. 3

B. 4

B. 5

B. 6

B. 7

Lithology: Samples B. 1 to B. 5 were taken from Section B (Text-fig. 2.1, 2.6). The sampling horizons in this part of the cliff section are dark grey, plant bearing, pelletal, silty limestones with gritty, sandy partings. Sample B. 6 was taken from the red and green shales which form the lowermost units of Section B, however this sample was barren. Sample B. 7 was taken from a grey argillaceous limestone with evaporite solution collapse features, in Section C (Text-fig. 2.1). The conglomeratic units in Section B and C (Text-fig. 2.1) are laterally equivalent making it possible to establish relative positions of samples taken from these sections. Sample B. 7 is therefore considered to be stratigraphically higher than B. 5.

Text-fig. 2.6 : View of Boswarlos section B

Crustacean fauna: *Youngiella* sp.

Amphissites sp. aff. *A. centronotus*

Acratia acuta

Acutiangulata n. sp. A.

"Neokloedenella" variolata

Chamishaella suborbiculata

Chamishaella n. sp. A.

Shishaella moreyi

Shivaella sp.

Polycope n. sp. A.

Tealliocaris sp. aff. *T. loudonensis*

2.2.2 St. George's Bay Coastline.

The sampling sites are summarised in Text-fig. 2.1.

1. Fischells Brook.

Locality: The sampling locality (Text-fig. 2.1) is situated on the northern bank of Fischells Brook, about 650m upstream of the Canadian National Railway bridge.

Samples: Fi. 1

Fi. 2

Fi. 3

Fi. 4 All barren.

Stratigraphy: The samples collected on Fischells Brook are from strata that immediately overlie a conglomerate horizon and are considered to be lateral correlatives of the Ship Cove Limestone (von Bitter and Plint-Geberl, 1982; Knight, 1983).

Lithology: Despite the fact that all samples from this 24m sequence are barren the lithologies are described, since they may have palaeoecological significance.

The samples were collected from grey, fine grained, plant bearing, mica rich shales located at 1m (Fi. 1), 7m (Fi. 2), 16m (Fi. 3) and 22m (Fi. 4), above the base of the sequence. Samples Fi. 1 and Fi. 2 are very mica rich, samples Fi. 3 and Fi. 4 are less rich in mica. No further samples were collected at this locality due to the predominance of massive limestone; and rippled units or flake congomerates, which would not be expected to yield ostracodes due to the high energy of deposition of the units.

For detailed lithological description of the sequence of Ship Cove Limestone equivalents, exposed in Fischells Brook the reader is referred to Knight (1983).

2. Stinking Cove.

Locality: The 740m Stinking Cove section (Bell, 1948, section G) is accessed by a stream gully that is found at the end of an unpaved track on the west side of Route 63, about 660m from the Robinsons junction. The cliff section (Text-fig. 2.7), from which the samples were taken, is to the north of the gully. Two lithologically distinct units were sampled, namely the *Nodosinella* Band and the Crabbes/ Jeffreys Limestone. The *Nodosinella* Band is equivalent to unit 3, the Jeffreys Limestone to unit 7, and the Crabbes Limestone to unit 9, in section G of Bell (1948). The Crabbes and Jeffreys Limestones were mapped by Bell (1948) as being separate units, however von Bitter and Plint-Geberl (1982) and Knight (1983) consider them to be

repetitions of the same unit. For location of the *Nodosinella* Band and Crabbes/Jeffreys Limestone sampling horizons, see Text-figs. 2.1, 2.7, 2.8.

Samples:			
	SC. Nodo. 2	SC. Jeff. 1	SC. Crab. 1
	SC. Nodo. 3*	SC. Jeff. 2*	SC. Crab. 2
	SC. Nodo. 4*	SC. Jeff. 3	SC. Crab. 3
	SC. Nodo. 5		SC. Crab. 4
	SC. Nodo. 6*		
	SC. Nodo. 7		
	SC. Nodo. 8*		
	SC. Nodo. 9*		
	SC. Nodo. 10		

* denotes ostracodes present in sample.

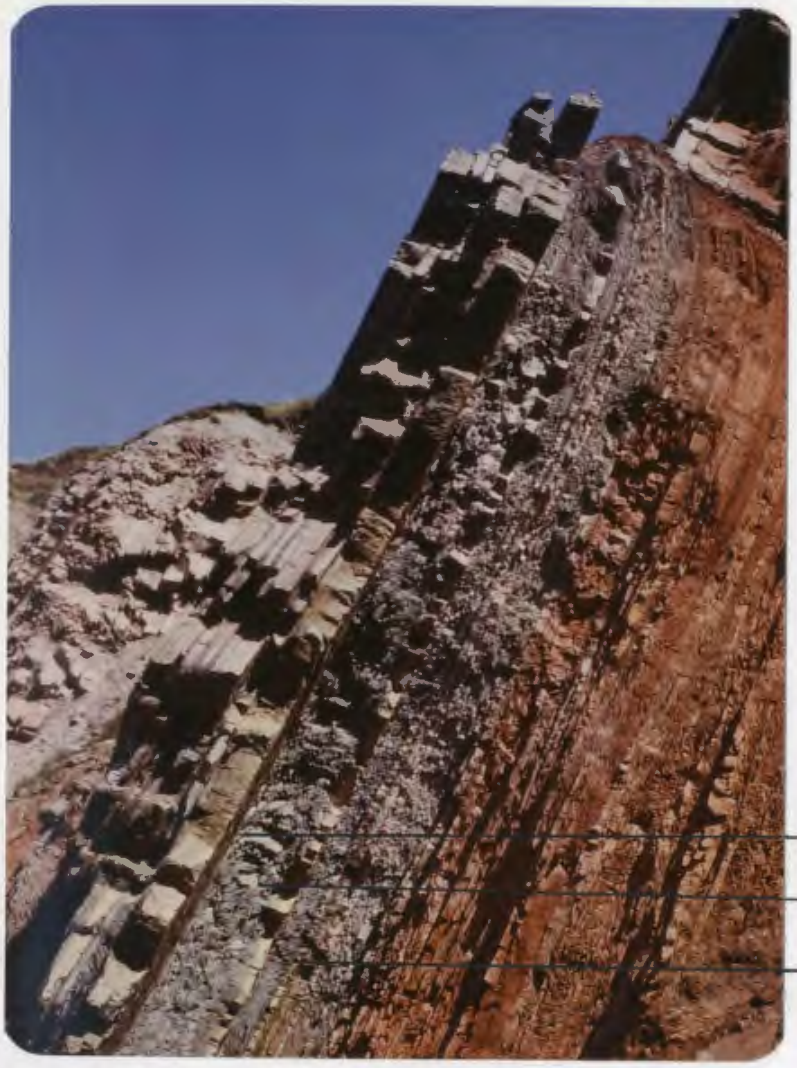
Additional samples from siliceous residues of the Crabbes/Jeffreys Limestone were supplied by Peter von Bitter and numbered CRABB 2.2, CRABB 2.5, JEFF 1.2. The localities for these samples are given in von Bitter and Plint-Geberl (1982)

Lithology: For detailed lithology of sample horizons and the thickness of units see Text-fig. 2.1

Stratigraphy: Samples collected from the *Nodosinella* Band are considered to be equivalent in age to the top of the lower Codroy Group (von Bitter and Plint-Geberl, 1982), and the Crabbes/Jeffreys Limestone samples are considered to be equivalent on age to the bottom of the upper Codroy Group (von Bitter and Plint-Geberl, 1982). These samples are also correlated with the top of the Jeffreys Village member of the Robinsons Road Formation (Knight, 1983) (Text-fig. 1.6)

Text-fig. 2.7 A
Crabbes Limestone
Jeffreys Limestone

Text-fig. 2.7 B
SC. Crab. 1
SC. Crab. 2
SC. Crab. 3
SC. Crab. 4



Text-fig. 2.7 C

Text-fig. 2.7

A : View of Stinking Cove section showing repetition of Crabbes/Jeffreys Limestone unit.

B : View of Crabbes Limestone showing sample positions.

C : View of Jeffreys Limestone showing sample positions.

Text-fig. 2.8 : View of *Nodosinella* Band, Stinking Cove, showing sample positions.

Ostracode fauna: A. *Nodosinella* Band.

"Copelandella" sp.

Acratia acuta

Acutiangulata aequalis

"Neokloedenella" variolata

Polycope n. sp. A.

Chamishaella suborbiculata

B. Crabbes/Jeffreys Limestone.

Gortanella sp.

Acratia acuta

kloedenellacean gen. et sp. indet. 1

Chamishaella suborbiculata

3. Crabbes River Mouth.

Locality: A 190m thick section from the Crabbes/Jeffreys Limestone to the *Nodosinella* Band is exposed on the northeast side of Crabbes River mouth. The beach is at the end of an unpaved path, the turnoff to which is situated at a right-angled bend 1.2km south of the Jeffreys junction on Route 63.

The *Nodosinella* Band (Text-fig. 2.9) and Crabbes/Jeffreys Limestone (Text-fig. 2.9) were sampled; and these units are equivalent to units (d) and (h) and (f) respectively, of section F (Bell, 1948). For localities of sampling sites see Text-fig. 2.1.

Samples: CR. Nodo. 1 CR. Jeff. 1

CR. Nodo. 2 Cr. Jeff. 2

CR. Nodo. 3*

CR. Nodo. 4* * denotes ostracodes present in samples.

Text-fig. 2.9 A

Text-fig. 2.9

A : View of Jeffreys Limestone exposed at Crabbes River mouth, showing sample positions.

B : View of the ripple surface at the top of the *Nodosinella* Band exposed at Crabbes River mouth.

C : View of the *Nodosinella* Band showing sample positions.

Text-fig. 2.9 B

Text-fig. 2.9 C

CR. Nodo. 4
CR. Nodo 3

CR. Nodo. 2
CR. Nodo. 1

Lithology: For detailed lithology of sample horizons and the thickness of the units see Text-fig. 2.1.

Ostracode fauna: *Acratia acuta*

Acutiangulata aequalis

"Neokloedenella" variolata

Geisina sp.

Chamishaella suborbiculata

Chamishaella n. sp. A.

4. Ship Cove.

Locality: The 35m thick Cormorant Limestone is exposed as a prominent black outcrop on the limb of a fold at the northeastern end of Ship Cove, 1¼km southwest of the mouth of Shoal Brook. Access to the brook is found about 500m upstream of the mouth, where an unpaved road crosses the brook. The crossing is located about 2¼km southwest of Highlands, just before the end of the road. (Text-fig. 2.1).

Sample: Cor. 1 - barren.

Lithology: The sample was taken from a black brachiopod rich limestone. Due to the lack of carbonate mud, the limestone has a high inter-and intra-particle porosity.

Stratigraphy: The Cormorant Limestone is considered to be near the top of the Codroy Road Formation according to the scheme established by Knight (1983) and roughly equivalent in age to the Black Point Limestone. Von Bitter and Plint-Geberl (1982), however, consider that the unit is equivalent in age to the lower part of the lower Codroy Group (Text-fig. 1.6). This discrepency cannot be resolved by the conclusions of the present study.

2.2.3 Codroy Coastline

The sampling sites are summarised in Text-fig. 2.1.

1. Capelin Cove.

Locality: Capelin Cove is situated at the end of an unpaved track about 2km from Millville, the access to which is on the left side of the road 200m after the Millville junction. The cliff section is to the southwest of the path and corresponds to section B of Bell (1948). Sampling horizons follow Bell's bed numbers, however, the section is very difficult to follow, making it possible to misidentify horizons according to Bell's scheme. In order to reduce this possibility to a minimum, easily identifiable horizons were established throughout the sequence, prior to detailed application of Bell's bed numbers to the whole section. The sequence is about 220m thick and was not remeasured in detail for this study since only isolated units within the sequence were sampled.

Samples and Lithology: Details of sample horizons and lithologies are given in Table 2.1.

Stratigraphy: The Capelin Cove section is considered by von Bitter and Plint-Geberl (1982) to be equivalent in age to the upper Codroy Group and is part of the Woody Cape Formation of Knight (1983) (Text-fig. 1.6). Knight (1983) indicates that the strata equivalent to section B of Bell (1948) are inverted and this is substantiated by the present author on the basis of field observations; therefore bed 43b (Bell, 1948) is the oldest and bed 12b (Bell, 1948) is the youngest horizon sampled.

Table 2.1 Samples and Lithology of Capelin Cove.

Ostracode sample number	Bell's Bed number	Sampling horizon thickness	Lithology
CC. 1	12b top	1m	Light grey, calcareous shale with about 5% mica.
CC. 2	23b middle	500mm	As above.
CC. 3	25b lower middle	250mm	Dark grey, calcareous shale with about 5% mica and plant fragments.
CC. 4	29b middle	250mm	Dark grey, calcareous shale, with mica, plant fragments, very rare brachiopods and rare subrounded granitic material.
CC. 5	36b top	400mm	Dark grey, calcareous shale with at least 10% mica.
CC. 6*	39b	1.5	Nodular dark grey calcareous shale with less than 5% mica associated with bivalves and brachiopods.
CC. 7*	40b	1m	Dark grey, calcareous shale with 5% mica.
CC. 8*	42b whole unit	small amounts taken over 8m	Dark grey, calcareous shale with gastropods, brachiopods, bivalves and 5% mica.
CC. 9*	43b top	500m	Pale grey, calcareous shale with about 5% mica and thin sandy partings. Contains rare conchostracans and broken brachiopods, gastropods and rare crinoid ossicles.

* Denotes ostracodes present in samples.

Crustacean fauna: *Acutiangulata aequalis*

Basslerella firma

"Neokloedenella" variolata

Geisina sp.

bairdiocypridid gen. et sp. indet. 2

Chamishaella suborbiculata

Tealliocaris sp. aff. *T. loudonensis*

2. Woody Cove.

Locality: The Woody Cove section is situated at the end of an un-named brook at Woodville, 3.7km northwest of the Millville junction. The brook empties into Woody Cove at about the middle of the "Gypsiferous zones" of Bell (1948, section D). Continuing southeast from this point, the sampling section begins after the last major unit of gypsum which Bell (1948) stated to be at least 20ft thick and formed of laminated dark and light grey bands associated with brecciated shales and siltstones. This unit is quite distinctive in that it is the last prominent feature of the cliff line prior to the beginning of the sampled section.

The sampled section, (Text-fig. 2.10), which is about 480m thick, begins with bed 38 of Bell (1948, section D), however, the presence of talus makes it very difficult to establish the exact position of this unit. Thirteen samples were collected from isolated horizons within this sequence above limestone units, or where fossil fragments were found.

Samples and Lithology: Details of sample horizons and lithology are given in Table 2.2.

Text-fig. 2.10

A: View of lower part of Woody Cove section.

B: View of upper part of Woody Cove section showing position of sample Wo. 10.

Text-fig. 2.10 A

Text-fig. 2.10 B

Table 2.2 Samples and Lithology of Woody Cove.

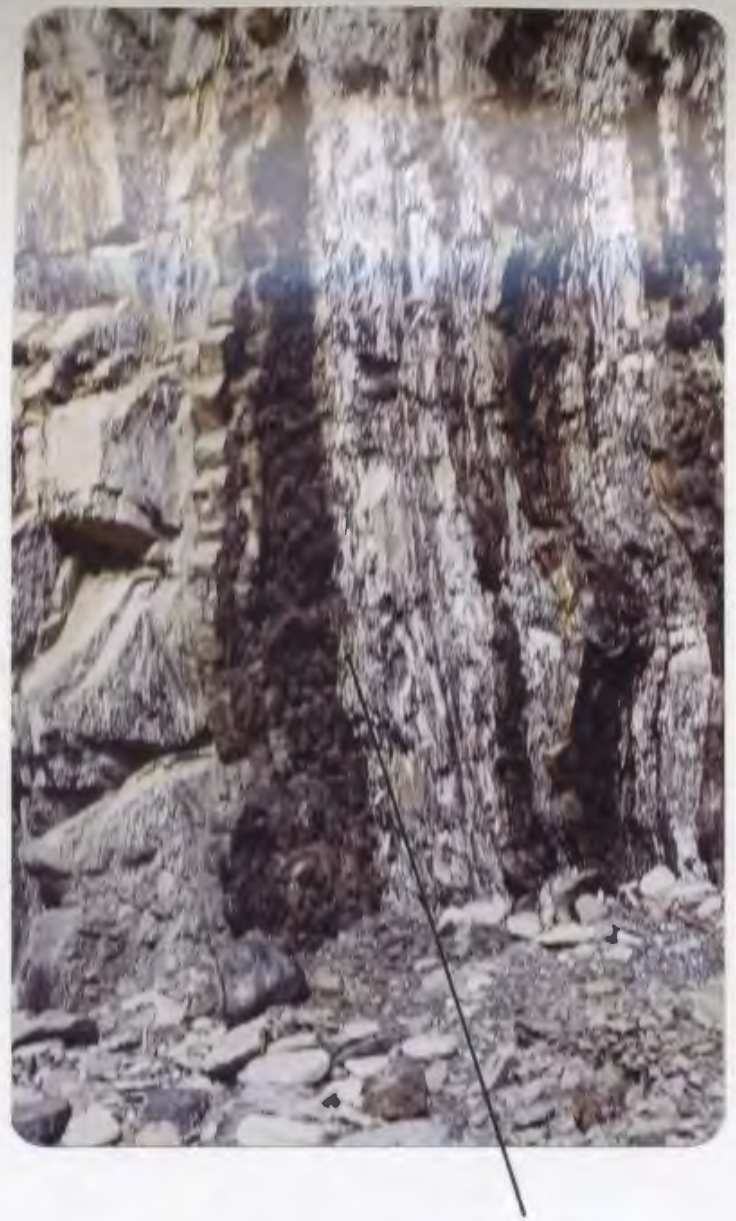
Ostracode sample number	Bell's Bed number	Sampling horizon thickness	Lithology[1]
Wo. 1	36	1m	Grey gypsiferous shale with less than 5% mica. Horizon underlies the last gypsum unit.
Wo. 2*	41/42	700mm	Very dark grey calcareous shale with 5% mica, occasional quartz grains and less than 5% gypsum, and a conchostrachan.
Wo. 3	54 top and 55 bottom	1.5m	Pale grey calcareous shale with about 10% mica and rare quarta grains. Interbedded with thin grey shaley limestone bands.
Wo. 4*	56 top	500m	Pale grey calcareous shale with 10% mica, rare quartz grains, also has very rare white gypsum needles. Overlies limestone band with brachiopods.
Wo. 5*	69 middle	1.5m	Medium grey calcareous shale with 5% mica, gastropod fragments and about 10% gypsum in the form of thick white needles. Overlies a grey shaley limestone band.
Wo. 6*	109	1m	Grey/black calcareous silty shale with 5% mica or less, occasional lithic fragments. Bed 109 is a very poorly defined unit. Sample taken in first bed not showing sedimentary structures.
Wo. 7*	109 top	1m	Pale grey calcareous shale, with occasional lithic fragments and rounded quartz grains, very little mica.
Wo. 8	121 middle	750mm	Pale grey calcareous shale with 10% mica.

Table 2.2 continued

Ostracode sample number	Bell's Bed number	Sampling horizon thickness	Lithology
Wo. 9*	125 top 126 bottom	1.5m	Dark grey calcareous shale with about 5% mica, also contains bivalves and gastropods.
Wo. 10*	143 bottom	500mm	Pale grey calcareous shale with 5% mica. Overlies an algal limestone (Bed 142) (Text-fig. 2.11).
Wo. 11	143 top	250mm	Pale grey calcareous shale with mica and rare gypsum crystals.
Wo. 12*	145	750mm	Dark grey calcareous shale with less than 5% mica, rare gypsum crystals, gastropods and conchostracans.
Wo. 13*	155	1m	Pale to medium grey and brown silty shale, shightly calcareous, with conchostracan fragments.

* Denotes ostracodes present in samples.

[1] Sample lithologies also contain notes about field relations where appropriate.



Text-fig. 2.11 A Wo. 10

Text-fig. 2.11 B

Text-fig. 2.11 A : Position of sample Wo. 10, overlying algal unit.

B : Close-up of low domal algal stromatolites.

Stratigraphy: The Woody Cove section is considered by von Bitter and Plint-Geberl (1982) to be equivalent in age to the upper Codroy Group and part of the Woody Cape Formation of Knight (1983). Knight (1983) mapped the section in Woody Cove as dipping to the south, and Bell (1948) measured the strata as a descending section. It is agreed by personal field observations that the section is the correct way up.

Ostracode fauna: *"Copelandella"* sp.
Bairdia sp. L.
Acutiangulata aequalis
Geisina sp.
Chamishaella suborbiculata
Chamishaella n. sp. A.
Shemonaella scotoburdigalensis

3. Black Point.

Locality: Black Point is a very distinctive needle-shaped feature of the coastline. Access to the Black Point Limestone is given by a path which runs along the top of the cliffs, at the northern end of Woody Cove (Text-fig. 2.1). Two spot samples were taken on the northern side of the point, however only part of the Black Point Limestone is accessible at low tide.

Sample: Bk. 1
Bk. 2

Lithology: Very fine grained, black, dolomitic limestone with very few fossil fragments.

Stratigraphy: The Black Point is thought to represent strata equivalent in age to the upper part of the lower Codroy Group (von Bitter and Plint-Geberl, 1982) and the upper Codroy Road Formation (Knight, 1983). Knight considers the unit to be roughly equivalent in age to the Cormorant Limestone.

Ostracode fauna: amphissitid gen. et sp. nov.

Acratia acuta

"Neokloedenella" variolata

Chamishaella suborbiculata

2.3 Nova Scotia.

The Nova Scotia samples are from Antigonish and Hants Counties and occur in strata the are equivalent to Windsor A, and B and E respectively, according to the faunal subzones established by Bell (1929).

2.3.1 Antigonish County.

1. Calpo Quarry.

Locality: Calpo Quarry is located about 6.4km north along a secondary road, which is 8km southeast of Antigonish on highway 104 (Text-fig. 2.1). The quarry itself is situated about 1km along the quarry access road. At the northwestern end of the quarry are two embayments excavated into the limestone wall. The north end of the most easterly of these embayments is the wall from which the sample was taken. At the time of collection a conglomeratic unit in the limestone was exposed and the sample was collected immediately above the conglomerate/limestone contact (Text-fig. 2.12).

Text-fig. 2.12 : View of sample locality in Calpo Quarry overlying conglomeratic unit.

Sample: NS. 4

Lithology: Massive, very fossiliferous, buff coloured, micritic limestone containing brachiopods, gastropods, bivalves, bryozoans and conularids.

Associated Lithology: The limestone at Calpo Quarry overlies a granodioritic intrusion, blocks of which may be isolated, or form conglomeratic units within the limestone.

Stratigraphy: Geldsetzer et al. (1980) suggest that the limestone is equivalent in age to the basal Windsor A limestones that are developed elsewhere in Nova Scotia.

Ostracode fauna: *Amphissites* sp. aff. *A. centronotus*
Bairdia sp. *L.*
Acratia acuta
Acutiangulata aequalis
"Neokloedenella" variolata
bairdiocypridid gen. et sp. indet. 2
Polycope n. sp. A.
Chamishaella suborbiculata
Shishaella moreyi

2.2.3 Hants County.

1. Herbert River.

Locality: About 24km northeast of Windsor on Route 14, past the village of Brooklyn is a turnoff to Scotch Village. About 1.4km northwest along that road, just after the Herbert River crossing is a campsite. The section is developed in the roadcut immediately after the campsite.

Sample: NS. 3

Lithology: Massive, dark, buff coloured bioclastic limestone, contains brachiopods, gastropods, bivalves, bryozoans, corals, crinoids, foraminiferids and tentaculitids.

Stratigraphy: Geldsetzer et al. (1980) assign the section informally to "Upper Windsor Formation". Personal communication with the field trip leaders suggested that sample NS. 3 was collected in the Kennetcook limestone unit, which is equivalent in age to the Windsor E subzone (Moore, 1967; pers. comm.).

Ostracode fauna: *Gortanella* sp.
Kirkbya n. sp. A.
Bairdia sp. L.
Bairdia brevis
Bairdiacypris quartziana
Acratia acuta
Acutiangulata aequalis
Monoceratina youngiana
Beyrichiopsis cornuta
bairdiocypridid gen. et sp. indet. 2
Polycope n. sp. A.
Chamishaella suborbiculata

2. Wentworth Quarry.

Locality: About 6km southeast of Windsor along Route 14 is a turnoff to Wentworth Creek, about 1km north along this road is the Wentworth Gypsum Quarry. Exact locations cannot be given for the samples since they were taken at sites in a working quarry. The sampling horizons

are situated to the east side of the haulage road.

Samples: NS. 5

NS. 6

Lithology: Dark brown/grey micritic limestone, with ostracodes and the ?bryozoan *Paleocrisidia*. Ostracode carapaces are often infilled with gypsum.

Associated Lithologies: The samples NS. 5 and NS. 6 are overlain by siltstone horizons and thick gypsum units. The gypsum unit overlying NS. 5 is much thicker than that which overlies NS. 6, and sample NS. 5 is also overlain by a siltstone horizon.

Stratigraphy: Geldsetzer et al. (1980) indicate that the Phillips (NS. 6) and Dimrock (NS. 5) limestones are part of the Windsor B subzone.

Ostracode fauna: *Acratia acuta*

Acutiangulata aequalis

Beyrichiopsis lophota

Paraparchites sp. aff. *P. kellettae*

Chamishaella subornticulata

2.4 Summary.

Samples for crustacean study were taken from five areas in the Atlantic region of eastern Canada and were predominantly collected from shale and limestone lithologies. The primary field area was in southwestern Newfoundland. The samples from Nova Scotia augment the main collection. Although the Nova Scotia samples are geographically and stratigraphically more isolated than those from Newfoundland, the faunas from these samples are different in several

aspects and therefore aid in giving a more complete idea of the taxa that occurred in the Maritime Basin during the early Carboniferous.

CHAPTER 3.

METHODS AND MATERIALS

3.1 Collecting procedure.

Collection of samples for ostracode examination was based upon several criteria. Samples were collected from lithologies that were part of a continuous sequence or from units that could be easily placed within an existing stratigraphy. In Newfoundland the collecting localities were therefore restricted by these parameters to the Ship Cove Limestone and its lateral correlatives, the *Nodosinella* band, the Crabbes/Jeffreys Limestone and marine bands in the Capelin Cove and Woody Cove sequences. In Nova Scotia the samples were collected during the Geological Association of Canada Field Trip 22 (Geldsetzer et al., 1980) wherever there was any probability of recovering ostracodes, and therefore represent spot samples.

Sampling was restricted further by the need to sample lithologies from which the ostracodes could be released. Siliceous residues from conodont samples, provided by Peter von Bitter of the Royal Ontario Museum, were an important addition where massive limestones occurred in the sequence.

Samples were collected from clean unweathered sediment to avoid contamination and to give good preservation. The intention was to collect samples representing the shortest possible time span, however, sample size would then be dependent upon the rate of sedimentation, no strict ruling could be applied. As a guideline samples were collected from the shortest convenient vertical thickness of strata, so that time averaging and thus stratigraphic and

ecological mixing would be kept to a minimum.

A total of 74 samples were collected, 43 of which contained ostracodes. The average sample weight was about 3-4kg.

Where sampling was possible over a continuous vertical sequence, the sampling interval was 0.5m or less.

3.2 Processing of material.

Each sample was macerated to about 10mm grain-size and placed in a 2½l stainless steel boiling pot. It was then covered in water and 6 tablespoons of Calgon, an inert water softener, were added. The sample was boiled and then simmered, and stirred intermittently to prevent charring.

If the sample broke down, the process was halted, however if no reduction of sediment was evident after 4 hours, 30% Hydrogen Peroxide was added in 25ml quotients until sediment reduction had been induced.

After reduction the samples were sieved at 63, 125, 250, 500 and 800 micron intervals. These fractions were washed into pyrex evaporating dishes, and, after excess water had been decanted off, were placed in an oven to dry. Each fraction was then bottled separately for ease of picking.

In the case of some of the more resistant samples fine needles and etching techniques were used to release the fossils.

Ostracodes were studied using a Carl-Ziess binocular microscope and a Cambridge "Stereoscan" Scanning Electron Microscope, Type 96113, Mark 2A. For the S.E.M. studies, specimens were mounted onto metal stubs using double sided tape and

coated in gold. Ostracodes were examined at 5kv acceleration, since at higher kvs charging became an acute problem. Individual specimens were photographed using a polaroid camera attachment on the S.E.M. Polaroid Type 665 Positive/Negative Panchromatic Black and White Land Film was used. The negatives were washed and then immersed in 12% sodium sulphite clearing solution prior to drying.

Malacostracans were mounted on plastic putty so that orientation could be varied; and photographed using a Wild Heerbrugg M8 stereoscopic microscope with an M400 photographic attachment. To give the best results, Kodak ET135 Ektachrome Black and White ASA 160 Tungsten Film was used.

3.3 Limitations to the study.

Evaluation of the ostracode faunas from the lower Carboniferous of Newfoundland and Nova Scotia has been beset by some problems that have limited the scope of the project.

One of the most critical factors has been the poor preservation of the ostracodes. In the Aguathuna samples, lead/zinc mineralisation has resulted in the remobilisation of calcite, consequently the fauna recovered from these localities is almost entirely composed of steinkerns. Ostracodes from the hypersaline environments are also poorly preserved and often deformed. The paucity of ostracodes in the Capelin Cove and Woody Cove sections has not been aided by their frequently crushed nature.

The net result of the poorly preserved material is that classification is frequently incomplete and new species cannot be properly described. Biometric analysis of steinkerns is not

recommended since the original carapace parameters cannot be measured. It should be recognised that, although length: height: width plots can be made to indicate instar groupings, the measurements will be consistently smaller than in non-steinkern material. The preservation of the material from Nova Scotia was generally much better.

A further limitation is caused by the nature of the sedimentary succession in southwestern Newfoundland. Since the succession is dominantly of non-marine origin with intercalated marine units, a continuous sequence of faunas could not be collected. This problem was exacerbated by the sparce faunas recovered from many of the samples, coupled with their poor preservation. These facts, together with the lack of more material from Nova Scotia has prevented the investigation of stratigraphic aspects of the ostracode faunas.

Despite these problems it has been possible to describe varied faunas from several types of environment and to demonstrate their detailed ecology.

CHAPTER 4

PALAEOECOLOGY

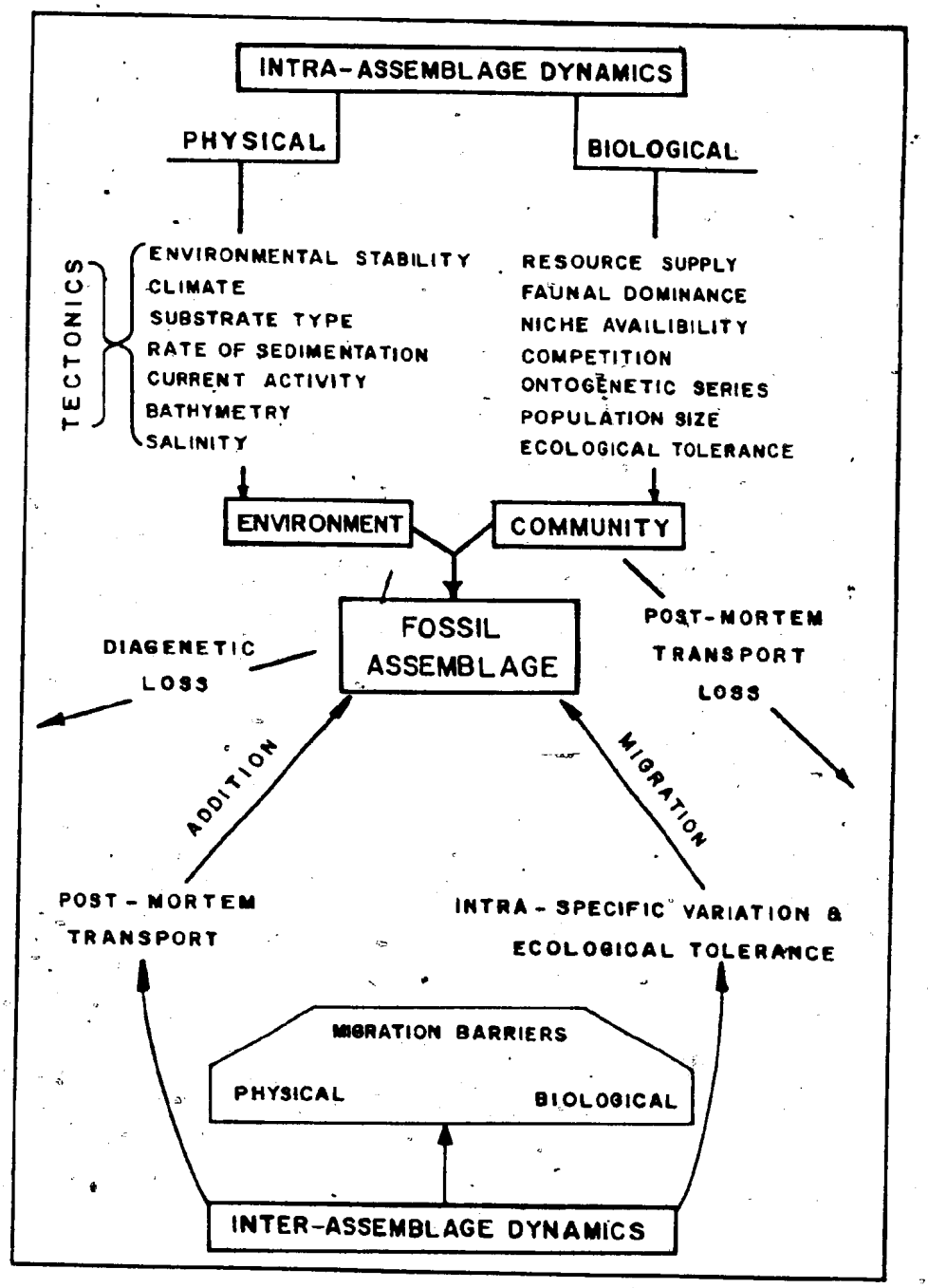
4.1 Introduction

This study shows that the 18,857 crustaceans collected from sampling localities in the middle Carboniferous sediments of Atlantic Canada can be used to delineate seven main fossil assemblages. The palaeoenvironmental stability and salinity were major factors in controlling the faunal content of the assemblages. All the assemblages show a marine affinity; three of the assemblages are derived from nearly normal marine palaeoenvironments (Assemblages I, II and VI); three are derived from hypersaline or fluctuating salinity palaeoenvironments (Assemblages III, IV and V); and one is derived from a predominantly brackish palaeoenvironment (Assemblage VII)

The assemblages are based upon several criteria including species occurrence, individual species abundances, other faunal elements present, sample lithology and associated lithologies. The inferred sedimentary environment is important in the definition of individual assemblages and in understanding the intra- and inter-assemblage dynamics. The major dynamic influences that result in observed fossil assemblage are summarised in Text-fig. 4.1. These dynamics give an indication of the dependency of the biological factors upon the physical factors, since the type of environment will affect the nature of the community established in it.

Using such features as valve to carapace ratios, instar proportions and degree of abrasion, it is possible to distinguish

Text-figure 4.1 : Chart showing the main physical and biological factors that control the nature of a fossil assemblage.


INTRA-ASSEMBLAGE DYNAMICS
PHYSICAL
BIOLOGICAL
TECTONICS
ENVIRONMENTAL STABILITY
CLIMATE
SUBSTRATE TYPE
RATE OF SEDIMENTATION
CURRENT ACTIVITY
BATHYMETRY
SALINITY
RESOURCE SUPPLY
FAUNAL DOMINANCE
NICHE AVAILIBILITY
COMPETITION
ONTOGENETIC SERIES
POPULATION SIZE
ECOLOGICAL TOLERANCE
ENVIRONMENT
COMMUNITY
FOSSIL ASSEMBLAGE
DIAGENETIC LOSS
POST-MORTEM TRANSPORT LOSS
ADDITION
MIGRATION
POST-MORTEM TRANSPORT
INTRA-SPECIFIC VARIATION & ECOLOGICAL TOLERANCE
MIGRATION BARRIERS
PHYSICAL
BIOLOGICAL
INTER-ASSEMBLAGE DYNAMICS

between possible *in situ* life assemblages or biocoenoses (Assemblages I, II (*pars*), III, IV) and possible derived, death assemblages or thanatocoenoses (Assemblages II (*pars*), VI and VII). It should be noted that so-called biocoenoses do not truly represent life-assemblage, since, even though they may be buried *in situ*, the resultant fossil assemblage consists of several generations of crustaceans that have been buried together. A true biocoenosis should allow for an estimation of the total standing crop at a given time, however, in none of the assemblages studied herein is that possible.

In summary therefore, the assemblages are the results of complex interactions of physical and biological factors, resulting in different faunal associations that may be directly related to the sedimentary environment in which they are found.

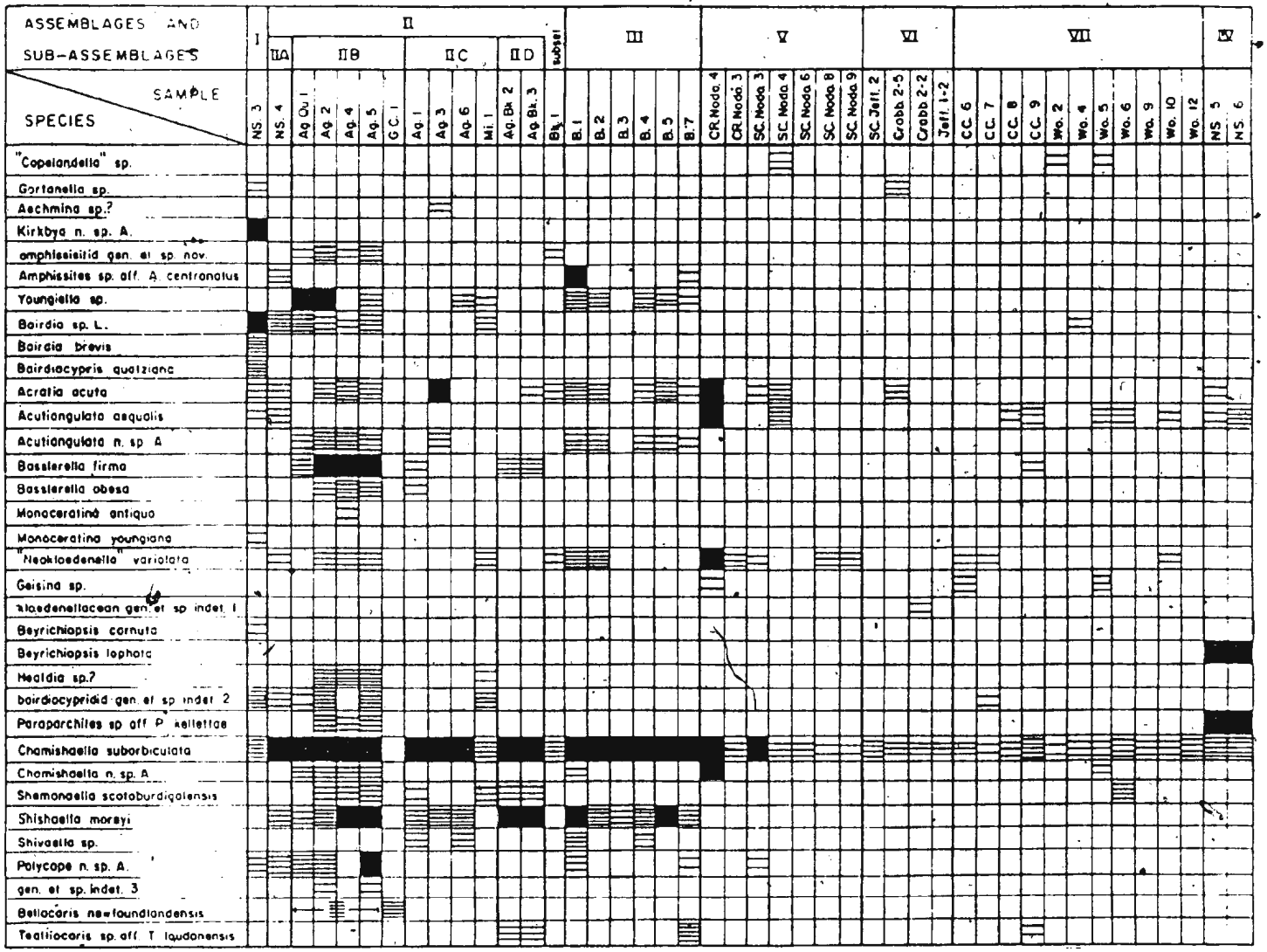
The individual samples, their faunal content and assemblage groupings are shown in Text-fig. 4.2.

4.2 Assemblage I

Assemblage I is restricted to the buff bioclastic limestone of sample NS. 3 collected from the Kennetcook Limestone. The ostracodes are associated with crinoid ossicles, coral fragments, endothyrid foraminifers, brachiopods, bivalves and gastropods. Macrofaunal species typical of the Kennetcook Limestone are described by Bell (1929), Sage (1954) and Moore and Ryan (1976). The environment of deposition is considered to be low energy, shallow subtidal marine (Moore, 1967) exhibiting a fairly normal marine salinity, as evidenced by the crinoids, corals and foraminifers.

Text-figure 4.2 : Sample grid showing species presence and abundance as well as assemblage groupings.

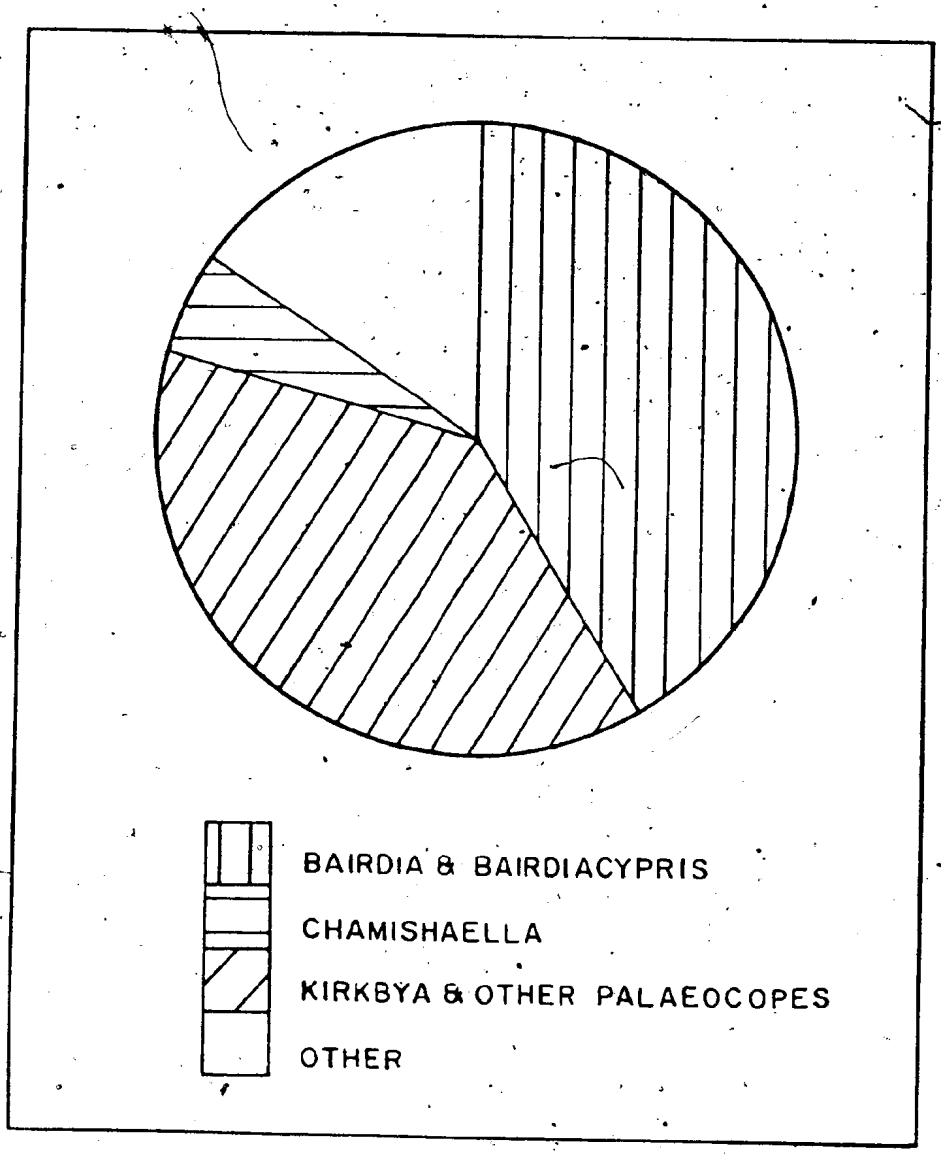
Key : number of specimens :


ASSEMBLAGES AND SUB-ASSEMBLAGES
SAMPLE
SPECIES
I
II
IIA
IIB
IIC
IID
subgel
III
V
VI
VII
IX
NS. 3
NS. 4
Ag Qu 1
Ag. 2
Ag. 4
Ag. 5
GC 1
Ag. 1
Ag. 3
Ag. 6
Mi. 1
Ag. Bk. 2
Ag. Bk. 3
Bk. 1
B. 1
B. 2
B. 3
B. 4
B. 5
B. 7
CR. Noda. 4
CR. Noda. 3
SC. Noda. 3
SC. Noda. 4
SC. Noda. 6
SC. Noda. 8
SC. Noda. 9
SC. Jeff. 2
Crabb 2-5
Crabb 2-2
Jeff. 1-2
CC. 6
CC. 7
CC. 8
CC. 9
Wa. 2
Wa. 4
Wa. 5
Wa. 6
Wa. 9
Wa. 10
Wa. 12
NS. 5
NS. 6
"Copelandella" sp.
Gortanella sp.
Aechmina sp.?
Kirkbya n. sp. A.
amphissiitid gen. et sp. nov.
Amphissites sp. aff. A. centronatus
Youngiella sp.
Bairdia sp. L.
Bairdia brevis
Bairdiacypris qualziana
Acratia acuta
Acutiangulata aequalis
Acutiangulata n. sp. A
Bassterella firma
Bassterella obesa
Monoceratina antiqua
Monoceratina youngiana
"Neoktoedenella" variolata
Geisina sp.
Xiaedenellacean gen. et sp indet. 1
Beyrichiopsis cornuta
Beyrichiopsis lophota
Healdia sp.?
bairdiocypridid gen. et sp indet. 2
Paraparchites sp aff. P. kellettae
Chamishaella suborbiculata
Chamishaella n. sp. A
Shemonaella scotoburdigalensis
Shishaella morsyi
Shivaella sp.
Polycope n. sp. A.
gen. et sp. indet. 3
Bellocaris newfoundlandensis
Teatliocaris sp. aff. T. laudonensis

The development of a gypsum unit that overlies the Kennetcook Limestone (Moore, 1967) would indicate that establishment of evaporite conditions took place after the deposition of the limestone. The presence of rare, small, poorly preserved tentaculitids in the sample may be evidence of their transportation into the area, since Babin (1980) suggests that they were planktonic organisms.

The assemblage of ostracodes is composed of 12 species from 11 genera, and although it is not the most diverse of the assemblages, it does contain more "normal marine salinity" ostracode indicators than any other assemblage described in this study. It also contains several species of minor abundance that give palaeoenvironmental information. The assemblage is characterised by the presence of *Kirkbya* n. sp. A., *Bairdiacypris quartziana* and two species of *Bairdia* as well as the low abundance of *Chamishaella suborbiculata* (Text-fig. 4.3). The ostracode associations of this sample supply evidence of an offshore, subtidal marine environment.

The most important component of the assemblage is the Bairdiinae, which, represented by *Bairdia* sp. *L.*, *Bairdia brevis* and *Bairdiacypris quartziana*, constitute 42% of the total fauna. Based upon studies of Recent *Bairdia* (Brady, 1880; Kornicker, 1961; 1964) it has been possible to show that species of the genus are vagrant benthic forms that exhibit the highest abundances in shallow, subtidal marine conditions where salinity ranges are about 30-40‰ and depth ranges from 10-200m. Brady (1880) suggested that *Bairdia* achieves its greatest diversity in tropical environments, and that where the genus dominates an ostracode assemblage it is only



Text-figure 4.3 : Percentage pie chart for the main components of Assemblage I.

represented by one or two species. Similar conclusions have been made with regard to Carboniferous occurrences of *Bairdia* by Ferguson (1962, 1974), Becker et al., (1974), Brondos and Kaesler (1976), Kaesler et al., (1977), Haack and Kaesler (1980), and Kaesler (1982) who suggest that *Bairdia* mostly occurs in stable offshore shelf environments. The diversity and abundance of Bairdiinae in this assemblage supports these conclusions.

The second main group occurring in Assemblage I are the palaeocopes, which account for 37% of the fauna. Palaeocopes present include rare specimens of *Gortanella* sp. and *Beyrichiopsis cornuta*, together with very abundant specimens of *Kirkbya* n. sp. A. Palaeocopes are thought to be more characteristic of nearshore rather than offshore environments, frequently being replaced by podocopid genera offshore, although kirkbyaceans may be common palaeocopes in the offshore (Kaesler et al., 1977; Kaesler, 1982). This observation is substantiated in Assemblage I by the rarity of *Gortanella* sp. and *Beyrichiopsis cornuta* and the relative abundance of *Kirkbya* n. sp. A..

It is significant that the only paraparchitacean species occurring in this assemblage, *Chamishaella suborbiculata*, only accounts for 5% of the total population. It has been suggested that *Paraparchites* and *Bairdia* may be ecologically separated, and that *Paraparchites*, which is more adaptable to unstable nearshore conditions, is replaced in the offshore by *Bairdia* which is less tolerant of environmental stress (Ferguson, 1962, 1974). There is also evidence that high abundances of paraparchitaceans may indicate brackish or hypersaline conditions (Sohn, 1971; Robinson, 1978; Dewey, 1982, in press). The low diversity and low abundance of

paraparchitaceans in Assemblage I, in association with other evidence presented, mitigates for a stable environment of near normal marine salinity.

Other minor elements of the fauna include rare *Monoceratina youngiana*. The genus *Monoceratina* is often a rare component of ostracode faunas (Roth, 1928; Sohn, 1977) and is positively correlated with fine sediments in shallow marine environments (Donze, 1971; Swain and Kraft, 1975; Sokac, 1977). The presence of ventro-lateral situated alae would suggest that *Monoceratina* was a benthic dweller, and used the alae for stability and support on soft substrates (Benson, 1975, 1981).

Also present in this assemblage are several specimens of *Polycope* n. sp. A.. Recent species of *Polycope* are recorded as being swimming or burrowing benthic ostracodes (Sars, 1928; Elofsen, 1941; Joy, 1974). Kornicker and Sohn (1976) suggest that the adventral spines present on morphologically similar species of Thaumatocypridídae are buoyancy regulators and they may have served a similar function in *Polycope* n. sp. A.. It is possible that *Polycope* n. sp. A. may be an interstitial form, due to its similarity to *Danielopolina orghidani*, a recent interstitial myodocopid (Danielopol, 1976; Kornicker and Sohn, 1976).

Less significant members of the assemblage include *Acratia acuta* which is a wide ranging species of little ecological significance, except that species of *Acratia* are frequently associated with other marine markers (e.g. Kellett, 1935; Cooper, 1946; Sanchez de Posada and Bless, 1971; Becker et al., 1974). Bairdiocypridid gen. et sp. indet. 2 is only found in Assemblages

I and II, and shows a positive correlation with the presence of *Bairdia* which supports the affinities of *Bairdiacypris* described by Becker et al. (1974). The rare occurrence of *Acutiangulata aequalis* seems to be anomalous since Robinson (1978) states that it may be indicative of brackish water environments, and its almost total absence from other truly marine assemblages in this study would tend to underline the anomaly.

When examined as a whole the assemblage shows a very high carapace to valve ratio, which, combined with the presence of instar series in the more abundant forms, e.g. *Bairdia* sp. *L.* (Text-fig. 6.9a) and *Kirkbya* n. sp. A. (Text-fig. 6.4), suggests that post-mortem transport was not important. The assemblage does not show a very high species diversity, however the presence of corals, crinoids and foraminiferids would suggest that salinity is not a controlling ecological factor. It is more likely that there were fewer niches available for colonisation in this assemblage than in the biohermal Assemblage II.

4.3. Assemblage II

4.3.1 Aguathuna and Calpo lithologies assemblage

Ostracodes that define Assemblage II are found at Calpo and Aguathuna Quarries in buff, bioclastic limestones (samples NS. 3, GC.1, Ag. Qu.1, Ag. 2, Ag. 4 and Ag. 5). They also occur in the dark grey shales at Aguathuna and Mistaken Cove (samples Ag. 1, Ag. 3, Ag. 6 and Mi. 1) and in the calcareous sandstones at Aguathuna Brook (samples Ag. Bk.1 and Ag. Bk. 2). These three lithologies broadly represent lateral facies variations.

In the bioclastic limestones the ostracodes are

associated with bryozoans, algae, conularids, brachiopods, bivalves, gastropods and conodonts; however corals, crinoids and foraminifers are notably absent. The dark grey shales only contain ostracodes and rare brachiopods. The calcareous sandstones contain ostracodes and plant debris. Macrofaunal elements typical of time equivalent strata to Assemblage II are described by Bell, (1929), Sage (1954), Moore and Ryan (1976) and Dix (1981). Samples that constitute Assemblage II are correlated with the time equivalent Ship Cove and Gays River Formations of Newfoundland and Nova Scotia respectively (Giles et al., 1979; Geldsetzer et al., 1980; Dix, 1981).

The bioclastic limestones of Assemblage II were deposited in a shallow, subtidal, marine environment that permitted the development of biohermal structures (Giles et al., 1979; Dix, 1981). In Newfoundland the bioherms grew in a nearshore drowned karstified terrain of valleys and collapsed caves (Dix, 1981); which agrees with the subtidal conditions implied for the northern part of the St. George's Bay sub-basin during the deposition of the Ship Cove Formation (Knight, 1983). In Nova Scotia, the bioherms grew upon drowned topographic highs (Geldsetzer, 1977, 1978; Kirkham, 1978; Giles et al., 1979; Giles, 1981); the Calpo Quarry Limestone being developed upon a granodioritic pluton (Sage, 1954; Geldsetzer et al., 1980). Biohermal overgrowth of karstified, drowned topographic highs has also been reported from the Dinantian of Belgium (Bless et al., 1980).

During the limestone deposition, stagnation of the sea resulted in an increase in salinity eventually leading to the onset of evaporitic conditions. Faunal evidence for an increased salinity

during the limestone deposition is provided by the restriction of foraminiferal diversity and a total absence of corals and crinoids in the sampled units. This is also supported by the dominance of *Cavusgnathus windsorensis* in the conodont assemblage of the Aguathuna limestone (von Bitter and Plint-Geberl, 1982); since this form is thought to indicate tolerance for raised or fluctuating salinities (von Bitter, 1976). *Cavusgnathus* is generally considered to be indicative of a nearshore, shallow subtidal environment (Austin, 1976; Higgins and Varker, 1982). Sedimentological evidence for raised salinities during the deposition of the Ship Cove Formation include the presence of moldic porosity after gypsum (Knight, 1983) in the sampled tidal flat sequence of the Ship Cove Limestone in Fischells Brook, and the development of gypsum in the overlying Codroy Road Formation (Knight, 1983). It is possible that, during the development of the bioherms, sea level fluctuations resulted in periodic exposure of the topographic highs in Nova Scotia, which subsequently led to the deposition of conglomeratic units (Text-fig. 2.13). In Newfoundland these events might be correlated with the deposition of grey shales (Text-fig. 2.2, 2.4) which represent the rapid influx of large amounts of terrigenous mud (Dix, 1981) and the possible temporary development of inhospitable conditions due to an increase in turbidity. These horizons may represent minor events with respect to eustacy and the Gondwanaland glaciation (Crowell, 1978), although it is beyond the scope of this study to examine this possibility.

The calcareous sandstones with ostracodes and plant fragments collected from Aguathuna Brook probably represent brackish

water nearshore conditions adjacent to the biohermal environments.

The three main lithotypes of Assemblage II outlined above support different ostracode faunas, which can be used to delineate sub-assemblages. The differences are interpreted as intra-assemblage environmental changes that relate primarily to substrate and depth variations. Inevitably they also reflect changes in environmental stability, resource supply and possibly salinity.

The four sub-assemblages are:

IIA, the bioclastic limestone sub-assemblage at Calpo

IIB, the bioclastic limestone sub-assemblage at Aguathuna

IIC, the grey shales sub-assemblage

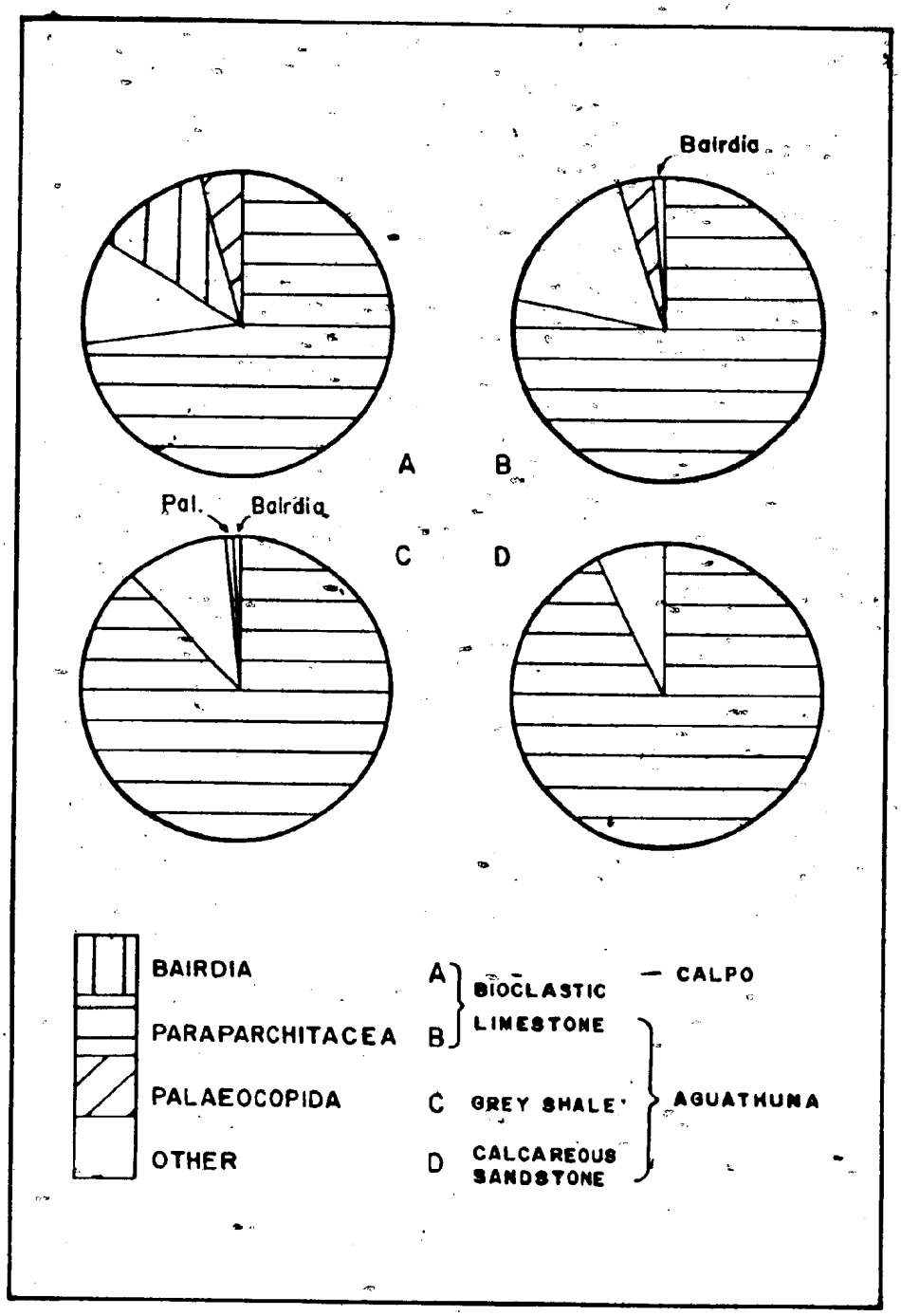
and IID, the calcareous sandstone sub-assemblage,

both deposited in the Aguathuna area. The relative percentages of the main ostracode components of these sub-assemblages are shown in Text-fig. 4.4.

Assemblage II is composed of 24 species representing 21 genera, and thus the most diverse assemblage with respect to numbers of species present; although the species to genus ratio is low.

The total assemblage is characterised by the presence of kirkbyacean palaeocopes, low abundances of *Bairdia* and high diversity and abundance of paraparchitaceans. The most important component of Assemblage II is the Paraparchitacea which is represented by *Paraparchites* sp. aff. *P. kellettae*, *Chamshaella suborbiculata*, *Chamishaella* n. sp. A, *Shemonaella scotoburdigalensis*, *Shishaella moreyi* and *Shivaella* sp., which as a group, can comprise about 80%

Text-figure 4.4 : Percentage pie chart for the main components of Sub-assemblages IIA, IIB, IIC and IID.


Bairdia
A
B
Pal.
Bairdia
C
D
BAIRDIA
PARAPARCHITACEA
PALAEOCOPIDA
OTHER
A
B
BIOCLASTIC LIMESTONE
CALPO
C
GREY SHALE
D
CALCAREOUS SANDSTONE
AGUATHUNA

of the total ostracode fauna. *Chamishaella suborbiculata* often dominates the assemblage by contributing up to ten times more individuals to the population than any other single ostracode species; *Shishaella moreyi* is the second most abundant ostracode in the assemblage. Other species of Paraparchitacea are much less common.

Only one species of *Bairdia* occurs within this assemblage and never accounts for more than 11% of the individuals present in any sub-assemblage. Comparisons of the growth charts for *Bairdia* sp. *L.* from Assemblage I (Text-fig. 6.9a) and from Assemblage IIB (Text-fig. 6.9b) indicate that although the instars from both assemblages fall into discrete clusters, the specimens in Assemblage II are lower and narrower than those in Assemblage I. Cadot and Kaesler (1973) showed that intraspecifically, Recent species of *Bairdia* are more variable in carapace morphology over a range of environments than other genera, and they suggested that populations of *Bairdia* represent highly variable gene pools. It is also thought that Palaeozoic species of *Bairdia* show a strong correlation with stable offshore subtidal environments (Ferguson, 1962; Becker et al., 1974; Kaesler, 1982). Therefore the presence of consistently smaller individuals and the apparent variation in outline (Pl. 6, figs. 1,5,7) of *Bairdia* sp. *L.* in Assemblage II would tend to support the conclusions of Cadot and Kaesler (1973), while the low abundance and absence of other *Bairdia* species would also suggest that Assemblage II represents the ecological limit of *Bairdia* occurrence, especially when the inverse relationship with paraparchitaceans is considered (Ferguson, 1962, 1974). The presence of 11% *Bairdia* in the bioclastic limestones of Calpo Quarry that form Sub-assemblage IIA indicates that this

sub-assemblage may have been in a slightly more offshore position than IIB, or IIC, in which *Bairdia* comprises only about 1% of the ostracode fauna. This substantiates the view that Gays River Formation lithologies in Nova Scotia developed on offshore subtidal topographic highs, (Geldsetzer, 1977; Giles et al., 1979). The distribution of kirkbyacean palaeocopes in Assemblage II underlines this conclusion. Kaesler (1982) suggests that kirkbyaceans are the only abundant palaeocopes in offshore environments. The kirkbyacean *Amphissites* sp. aff. A. *centronotus* constitutes 3% of Sub-assemblage IIA, whereas amphissitid gen. et sp. nov. and *Youngiella* sp. constitute less of the total ostracode faunas of Sub-assemblages IIB and IIC. This would suggest that Sub-assemblage IIA was further offshore than IIB and IIC, however it was not as far offshore as Assemblage I. Kirkbyacean palaeocopes are totally absent from Sub-assemblage IID.

The absence of other palaeocopes from Assemblage II may be a function of the abnormality of the environment and their inability to compete with more adaptable forms for niche space.

The benthic marine myodocopid, *Polycope* n. sp. A, is more abundant in Sub-assemblage IIB than in Sub-assemblage IIA, and much more abundant than in Assemblage I. This implies that the species was suited to nearshore environments. If the species had an interstitial habitat, the sheltered bioherms developed in the drowned karstified environment of Sub-assemblage IIB could support a greater population of *Polycope* n. sp. A. than the more exposed bioherms of Sub-assemblage IIA, or the more offshore environment of Assemblage I, as suggested for some recent species of Polycopacea

and Thaumatocypridacea (Danielopol, 1976, 1980).

Other members of the assemblage that indicate a marine affinity tend to be restricted to Sub-assemblages IIA and IIB. Occurrences of bairdiocypridid gen. et sp. indet. 2 generally shows a positive correlation with *Bairdia* as suggested for *Bairdiocypridis* and *Bairdia* by Becker et al., (1974), however, its absence from some samples containing *Bairdia* might indicate that it was a more ecologically restricted species. *Healdia* sp.? and *Bassleriella* spp. are also indicators of shallow marine conditions (Brondos, 1974; Brondos and Kaesler, 1976; Sanchez de Posada, 1977; Haack and Kaesler, 1980). *Monoceratina antiqua* is considered to be a benthic shallow subtidal species in the same manner as *M. youngiana* in Assemblage I. The low abundances of *"Neokloedenella" variolata* in Assemblage II may indicate that it was better suited to the more extreme conditions represented by Assemblages III and IV.

The peracarid *Bellocaris newfoundlandensis* is often found in clusters throughout the bioclastic limestones of the Aguathuna area (Fong, 1972; Dix, 1981; Dewey and Fahraeus, 1982), which led Dewey and Fahraeus (1982) to suggest that nutrient supply in the bioclastic limestones was high and that the scavanging peracarids tended to collect around a food source.

On examination of growth curves for several species from Sub-assemblage IIB e.g. *Acratia acuta* (Text-fig. 6.10a), *Bairdia* sp. *L.*, (Text-fig. 6.9b), *Basserella* spp., (Text-figs. 6.6. 6.13, 6.14) as well as the paraparchitaceans (Text-figs. 6.24, 6.25, 6.27, 6.28) it is clear that within the bioclastic limestones post-mortem transport was not a critical factor. Growth curves for most

species form discrete instar clusters, but this is less so with regard to *Acratia acuta* and the paraparchitaceans, which supports the conclusions of Ferguson(1974, 1976) who noted almost continuous growth patterns in *Paraparchites* from the Abden limestone of Scotland; and also suggests that time averaging of the samples is not important (see section 4.10.3).

Sub-assemblage IIC, which is characteristic of the grey shale horizons interbedded with Sub-assemblage IIB lithologies, supports a much reduced fauna that shows a high valve to carapace ratio and restriction of size groupings. This indicates that post-mortem transport was an important factor of this sub-assemblage and is in accord with the suggestion that valve-carapace ratios are not reliable unless they compare identical species in an environment (Kilenyi, 1969, 1971). The unit represents a rapid influx of terrigenous mud, probably associated with the temporary development of very turbid conditions. This would have been catastrophic for the large numbers of filter feeders in Sub-assemblage IIB.

Sub-assemblage IID is the most restricted assemblage and is composed almost exclusively of *Chamishaella suborbiculata* and *Shishaella moreyi* with 8% of other species. It is interesting to note the presence of *Acratia acuta* in each of the sub-assemblages which indicates a very wide ecological tolerance for this species. The peracarid *Tealliocaris* sp. aff. *T. loudonensis* also occurs in this environment. Since this form is also associated with the hypersaline portions of Assemblage III it is possible that *Tealliocaris* has a wide salinity tolerance. It is suggested that the calcareous sandstones and plant debris are indicators of a marginal brackish

environment. *Tealliocaris* sp. aff. *T. loudonensis* only occurs rarely in association with *Bellocaris newfoundlandensis* in Sub-assemblage IIB. *B. newfoundlandensis* is considered to represent a species that is restricted to relatively stable nearshore environments, and *Tealliocaris* sp. aff. *T. loudonensis* is a more euryhaline opportunistic species but unable to compete with *B. newfoundlandensis* in the more stable environments. Therefore, it would appear that the migration barrier against *B. newfoundlandensis* between Assemblages II and III is a one-way salinity barrier, and for *Tealliocaris* sp. aff. *T. loudonensis* represents a competition barrier.

4.3.2 Black Point Limestone subset

Ostracodes of the Black Point Limestone are rare and consist of only 4 species from 4 genera, which are all found in Assemblage II.

The Black Point Limestone, which is correlated with the top of the Codroy Road Formation (Knight, 1983) (Text-fig. 2.1) is a black, massive, poorly fossiliferous dolomitic limestone. The associated fauna includes rare bivalves, gastropods and some brachiopods. The presence of the conodont *Cavusgnathus* is indicative of shallow marine conditions (von Bitter, 1976: von Bitter and Plint-Geberl, 1982). The environment of deposition is considered to have been a nearshore, hypersaline environment (Knight, 1983) supporting an impoverished fauna.

The ostracodes present include *Chamishaella suborbiculata*, amphissitid gen. et sp. nov., *Acratia acuta* and

"Neokloedenella" variolata. The presence of *C. suborbiculata* and *A. acuta* is not surprising since they are interpreted to be euryhaline species. Amphissitid gen. et sp. nov. may indicate a subtidal marine influence, but the rare occurence cannot be used with confidence. *"N." variolata* is thought to be more adapted to slightly hypersaline or brackish environments which would explain its occurrence in such a restricted association.

Since all the species present in the assemblage also occur in Sub-assemblage IIB it is concluded that the association represents a subset of Assemblage II. It is, however, possible that further work might reveal that the Black Point Limestone ostracodes form a discrete assemblage as is indicated by the restriction of the other faunal elements and the lithology.

In conclusion, ostracodes from Sub-assemblages IIA and IIB indicate that the environment was a slightly hypersaline shallow nearshore environment as evidenced by the percentage proportions of Kirkbyacea, *Bairdia* and paraparchitaceans. The percentage of kirkbyaceans and *Bairdia* would suggest a deeper water environment for Sub-assemblage IIA than IIB.

Sub-assemblage IIC represents inhospitable conditions associated with rapid influx of terrigenous mud, transport of ostracodes, and reduction of diversity.

Sub-assemblage IID represents a brackish basin marginal environment. In part, Assemblage II is equivalent of Assemblage I of Dewey (in press).

4.4 Assemblage III

Assemblage III ostracodes are found at Boswarlos in the grey plant bearing, pelletal, silty, sandy limestones of section B, and the grey argillaceous limestones, with evaporitic solution collapse features of section C, (Text-fig. 2.1). The associated fossils include plant fragments and a restricted fauna of bivalves and gastropods. The Boswarlos section is correlated with the Ship Cove Formation (Dix, 1981; Knight, 1983).

The environment of deposition is considered to have been a nearshore shallow water basin influenced by fresh water influx in its early stages and stagnation and hypersalinity in its later stages (Dix, 1981).

The lower units of the Boswarlos section (samples B.1 - B.5) are characterised by silty limestones with coarse sandy partings. There is a lack of sedimentary structures, which would imply a quiet environment, whereas the coarse horizons suggest periodic current activity. The presence of plant material would mitigate in favour of a nearshore environment. There are no sedimentary features indicative of raised salinities. The associated fauna of bivalves include *Anthraconaia* and *Carbonicola* which would indicate a brackish salinity (Broadhurst, 1959; Pollard, 1969). The early stages of the environment could be considered as a quiet, nearshore, fluvially influenced lagoon.

The upper parts of the Boswarlos section (sample B.7) are characterised by grey silty limestones exhibiting extensive solution collapse features. This is evidence of hypersalinity, which

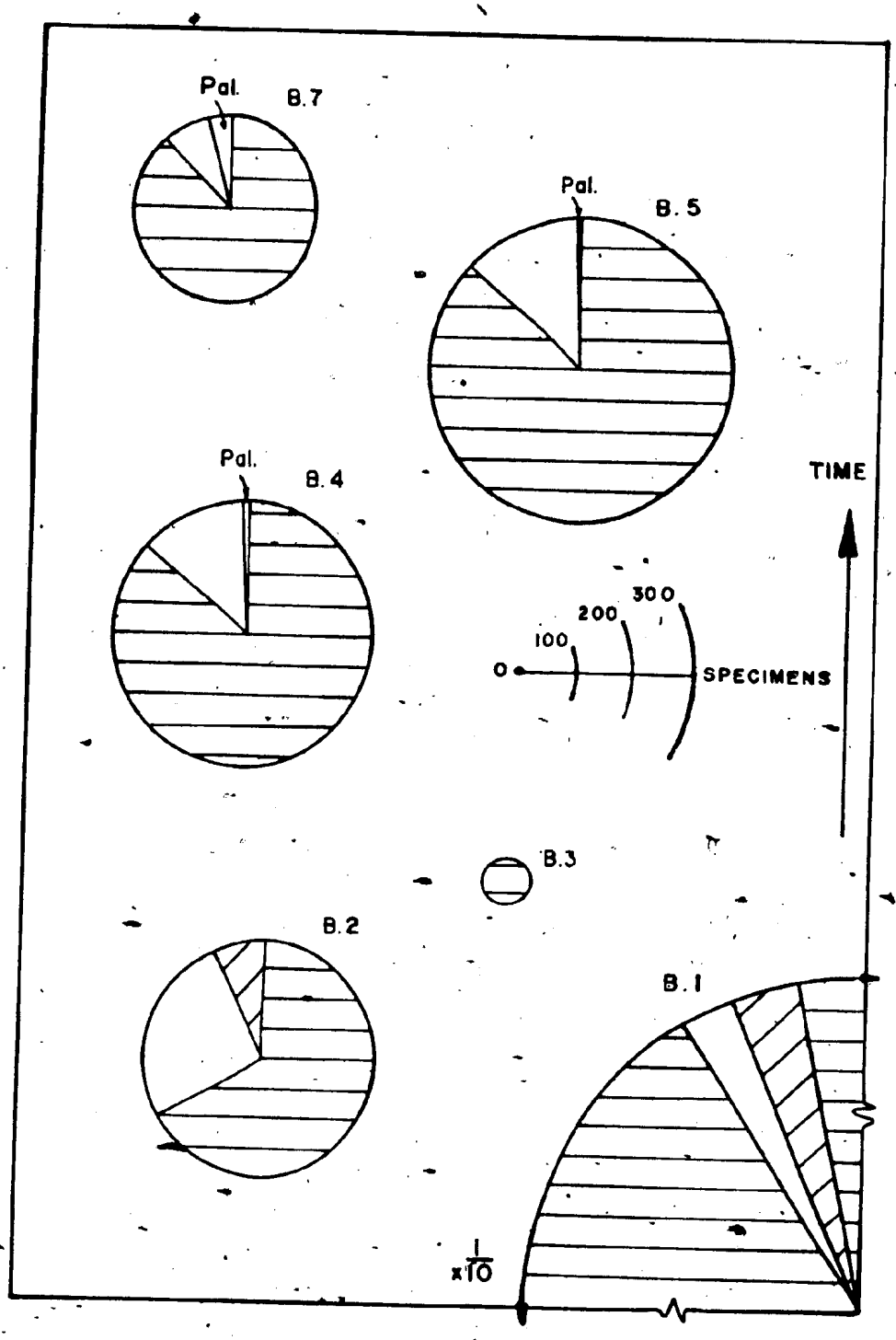
Text-figure 4.5 : Percentage pie chart for the individual samples of Assemblage III.

Note : a. Key is the same as Text-figure 4.4

b. Each chart is proportional in size to the number of specimens in each sample.

c. chart for B.1 is reduced by a factor of 10.

d. sample B.6 is barren and was taken below B.1.


Pal.
B.7
Pal.
B.5
Pal.
B.4
TIME
300
200
100
0
SPECIMENS
B.3
B.2
B.1
x 1/10

may have been caused by isolation of the lagoon, and arid conditions together with the termination of the fluvial influences.

Although the main constituents of the assemblage remain constant, the ostracodes that define Assemblage III can be used to illustrate the environmental changes that occurred during the deposition of samples B.1 - B.7. At its maximum development, ostracode Assemblage III consists of 11 species from 10 genera. The main component of the assemblage is the Paraparchitacea which is represented by *Chamishaella suborbiculata*, *Chamishaella* n. sp. A., *Shishaella moreyi* and *Shivaella* sp.. *Chamishaella suborbiculata* dominates the assemblage and *Shishaella moreyi* is the only other ostracode to occur consistently in the assemblage.

The inverse relationship between occurrences of paraparchitaceans and *Bairdia* is borne out be the absence of the latter from Assemblage III.

Kirkbyacean palaeocopes, thought to indicate stable shallow marine conditions (Kaesler, 1982), are represented by *Amphissites* sp. aff. A. *centronotus* and *Youngiella* sp. in this assemblage: their intermittent occurrence and relative scarcity would, however, suggest that they were at the limit of their ecological range.

The only other species occurring in this assemblage are *Acratia acuta*, *Acutiangulata* n. sp. A., *"Neokloedenella" variolata* and *Polycope* n. sp. A. The presence of *A. acuta* is further evidence of its wide ecological tolerance, since it is often the third most abundant species in the assemblage. *"Neokloedenella" variolata* is

only found in the lower samples but is more abundant in this assemblage than in Sub-assemblage IIB, suggesting the conditions are more favourable for its occurrence. *Polycope* n. sp. A. only occurs as a rare component of the lowermost and topmost samples, indicating its inability to tolerate the environmental fluctuations characteristic of this assemblage.

Although the major compositional elements of the assemblage appear to be relatively constant (Text-fig. 4.5) there is a definite stratigraphic change in species diversity and numerical abundances from sample B.1 to sample B.7. Text-fig. 4.5 shows that the number of individuals per sample was diminished by a factor of 50 between sample B.1 and B.3. There was, however, a recovery of both diversity and abundance from sample B.3 to B.7. Although sample B.7 exhibits a diversity increase (Text-fig. 4.6) it also exhibits a decrease in population size.

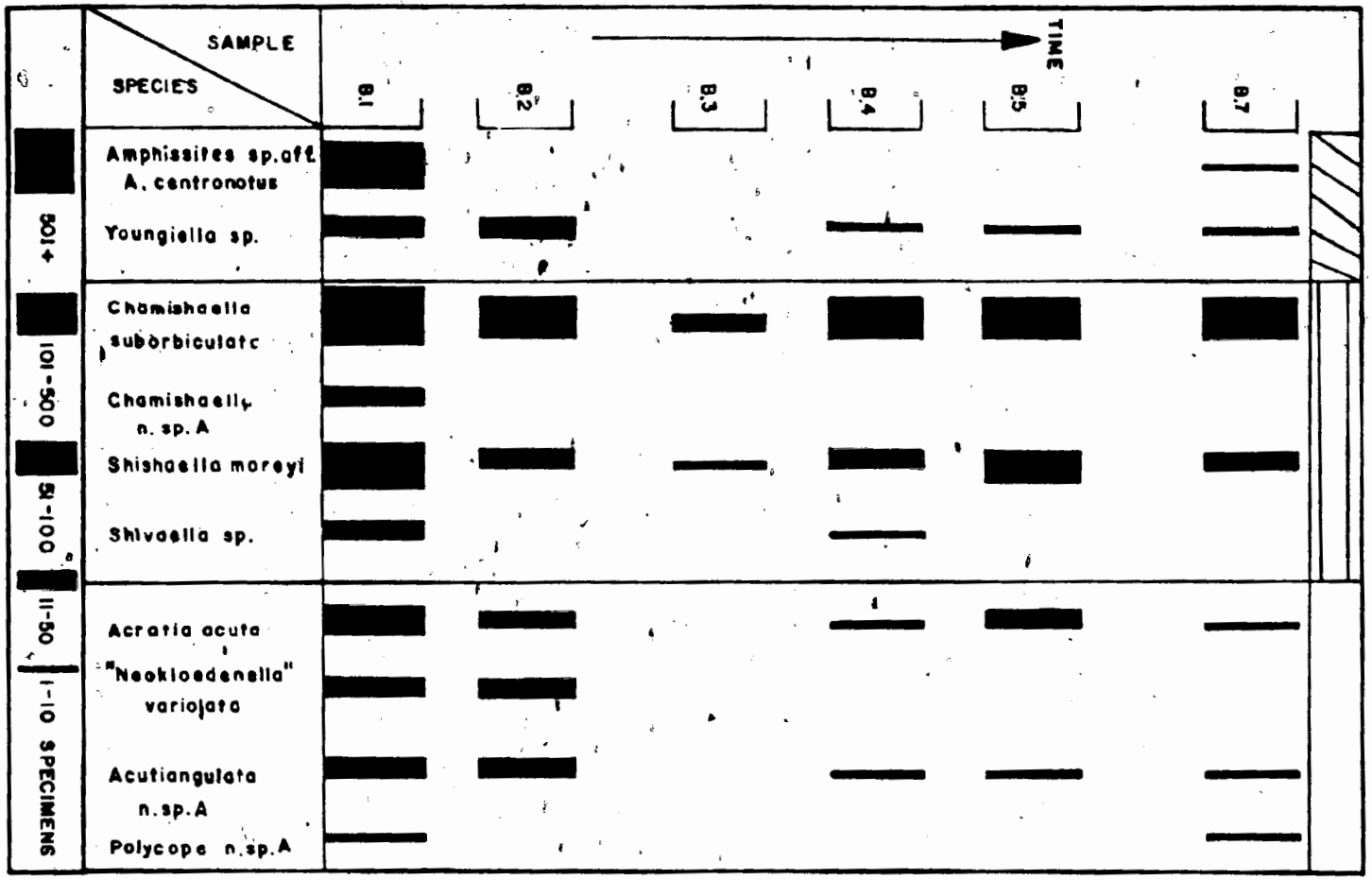
Sample B.1 supports the most diverse and abundant fauna of the assemblage (Text-fig. 4.6). It probably represents the initial transgression and initiation of a lagoonal facies colonised by a low diversity community of predominantly opportunistic species such as the paraparchitaceans. The presence of *Polycope* n. sp. A., *Youngiella* sp., but more especially *Amphissites* sp. aff. *A. centronotus* would suggest a marine affinity.

As the envrionment deteriorated, possibly as a result of fluvial influences including a lowering of the salinity and an increase in clastic input, the assemblage became more restricted, to the final exclusion of all species except *Chamishaella suborbiculata* and *Shishaella moreyi* in sample B.3 (Text-fig. 4.6)

Text-figure 4.6 : Sample chart showing fluctuation of species representation and abundance in Assemblage III.

Note : a. Key is the same as Text-figure 4.4.

b. Stratigraphic distances between samples are proportional.


SAMPLE
SPECIES
TIME
B.1
B.2
B.3
B.4
B.5
B.7
501 +
101-500
51-100
11-50
1-10 SPECIMENS
Amphissites sp.aff. A. centronotus
Youngiella sp.
Chamishaella subòrbiculatc
Chamishaella n. sp. A
Shishaella moreyi
Shivaella sp.
Acratia acuta
"Neokloedenella" variolata
Acutiangulata n.sp.A
Polycope n.sp.A

It is possible to account for the increase in diversity and abundance in samples B.4 and B.5 by a decline in fluvial runoff and with subsequent increase in salinity.

The final increase in diversity with associated decrease in abundance, encountered in sample B.7 may be the result of passing through normal marine salinities and entering hypersaline conditions as the lagoon began to stagnate and fluvial influences terminated. The peracarid *Tealliocaris* sp. aff. *T. loudonensis* occurs in the lower parts of the hypersaline portion of the sequence. Schram (1981a) suggests that *Tealliocaris* is a scavenger or low-level predator tolerant of brackish environments, therefore its occurrence in a hypersaline environment suggests a wider ecological adaptation. It is probable that its occurrence in this environment is due to its inability to compete with *Bellocaris newfoundlandensis* in Assemblage IIB and its wide ecological range. Unlike the occurrence of groups of peracarids in Assemblage IIB, *Tealliocaris* sp. aff. *T. loudonensis* occurs more randomly in this assemblage. Since nutrients would have been less plentiful in the hypersaline environment, the tealliocarid individuals would have been more randomly distributed in their search for food, as suggested by their occurrence in the shaley limestones of Assemblage III.

There is a high carapace to valve ratio in most samples (B.1, B.2, and B.7), and ontogenetic series of *Amphissites* sp. aff. *A. centronotus* (Text-fig. 6.6), *Chamishaella suborbiculata* (Text-fig. 6.25b) and *Shishaella moreyi* (Text-fig. 6.28b) would mitigate against post-mortem sorting. It is probable that *in situ* disassociation of paraparchitacean valves, due to the simple nature of the

paraparchitacean hinge, could simply have been caused by gentle current activity (Kilenyi, 1971 and Kontrovich and Nicolich, 1979).

The ostracode assemblage supports the conclusion that after the development of an enclosed carbonate lagoon; fluvial influences and terrigenous input resulted in a brackish mixed clastic and carbonate environment until the fluvial runoff ceased and an arid climate permitted the development of hypersalinity associated with the onset of evaporitic conditions.

This then, shows the adaptive potential of the paraparchtiaceans, which are the only group to persist throughout the changes in environmental salinity.

This assemblage in equivalent to Assemblage II of Dewey (in press).

4.5 Assemblage IV

Assemblage IV is restricted to the Dimrock and Phillips limestones (samples NS. 5 and NS. 6) that occur in Wentworth Quarry. The Dimrock Limestone overlies the Phillips Limestone, and both are considered to be part of the Windsor faunal zone B (Geldsetzer et al., 1980). The limestones are interbedded with siltstones and evaporites. The repetitive nature of the limestone-siltstone-evaporitic sequence implies a series of transgressive-regressive cycles (Geldsetzer et al., 1980), of which the Dimrock and Phillips triplets are part. The evaporites are interpreted as being of supratidal sabkha origin (Geldsetzer et al., 1980). On the basis of lithological and faunal evidence the limestones suggest a shallow, subtidal hypersaline environment. The associated fauna consists of

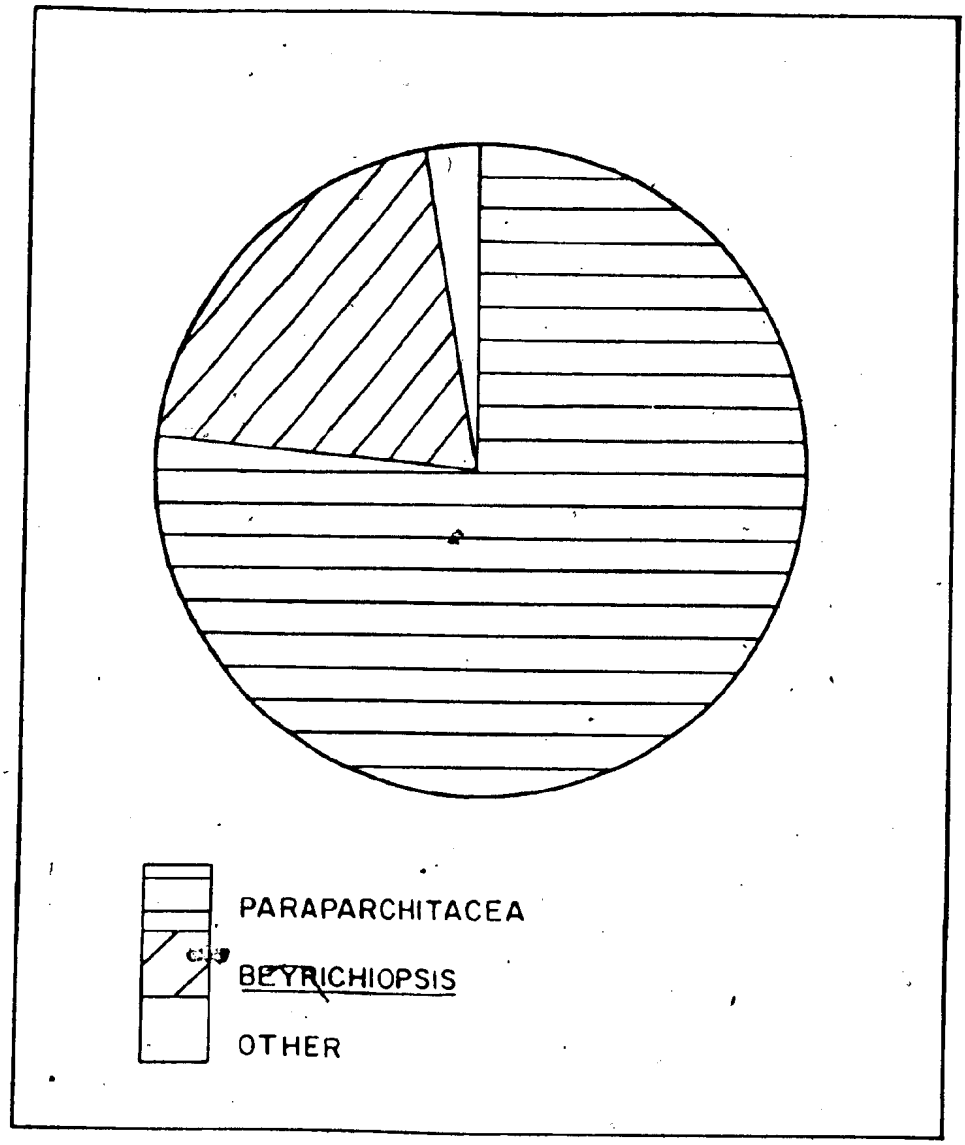
rare brachiopods and the bryozoan? *Palaeocrisidia*.

The ostracode assemblage consists of 5 species of 5 genera. The assemblage is dominated by the Paraparchitacea; the dominant species is *Paraparchites* sp. aff. *P. kellettae*. This is the only assemblage not dominated by *Chamishaella suborbiculata* since it is only the third most abundant species in the assemblage.

The inverse relationship between Paraparchitacea and *Bairdia* is evidenced by the absence of the latter from this assemblage, thus arguing in favour of a nearshore environment. *Beyrichiopsis lophota* is the second most abundant species and together with the Paraparchitacea it accounts for 96% of the fauna. (Text-fig. 4.7). *Beyrichiopsis* is also an indicator of marginal environments (Becker et al., 1974). A minor element of the ostracode fauna includes a few individuals of the apparently euryhaline species *Acratia acuta* which is suggested to have occurred at the limits of its ecological tolerance.

On the basis of low diversity and high abundances, the assemblage is postulated to be a low-level community. The large numbers of individuals may be the result of a lack of competition rather than high nutrient supply (Levinton, 1970); suggesting that the physical environment is the major control of diversity.

Beyrichiopsis lophota and *Paraparchites* sp. aff. *P. kellettae* both show a large size range of species groups (Text-figs. 6.18 and 6.23) which would imply *in situ* burial rather than post-mortem transport. The lack of discrete instar groups, however, may reflect continuous breeding cycles and overlapping



Text-figure 4.7 : Percentage pie chart for the main components of Assemblage IV.

generations of instars (see section 4.10.3), or time averaging of samples.

In summary Assemblage IV represents a nearshore, hypersaline carbonate environment colonised by opportunistic ostracodes, due to its unsuitability to colonisation by other species.

4.6 Assemblage V

Assemblage V is restricted to the *Nodosinella* Band at Crabbes River Mouth and Stinking Cove, and is equivalent to Assemblage III of Dewey (in press). The *Nodosinella* Band is equivalent in age to the top of the lower Codroy Group (von Bitter and Plint-Geberl, 1982) and the top of the Jeffreys Village Member (Knight, 1983) (Text-fig. 1.6).

Sediments of the *Nodosinella* Band consist of a series of intermittently calcareous shales and sandstones. The upper sandstone units exhibit low amplitude bifurcating ripples (Text-fig. 2.9B) and concretionary horizons occur within the shales (Text-fig. 2.1). Thin gypsum beds and sampled horizons containing from 0-10% synsedimentary gypsum imply a fluctuating salinity from near normal marine to hypersaline.

The shales and concretions are indicative of a quiet energy environment, whereas the sandstones indicate higher energy conditions. The ripple-marked surfaces of sandstones are indicative of a subtidal setting (Knight, 1983).

The associated fossils include the bivalves *Lithophaga poolii*, *Aviculopecten*, gastropods and the bryozoan? *Palaeocrisidia* as well as conodonts.

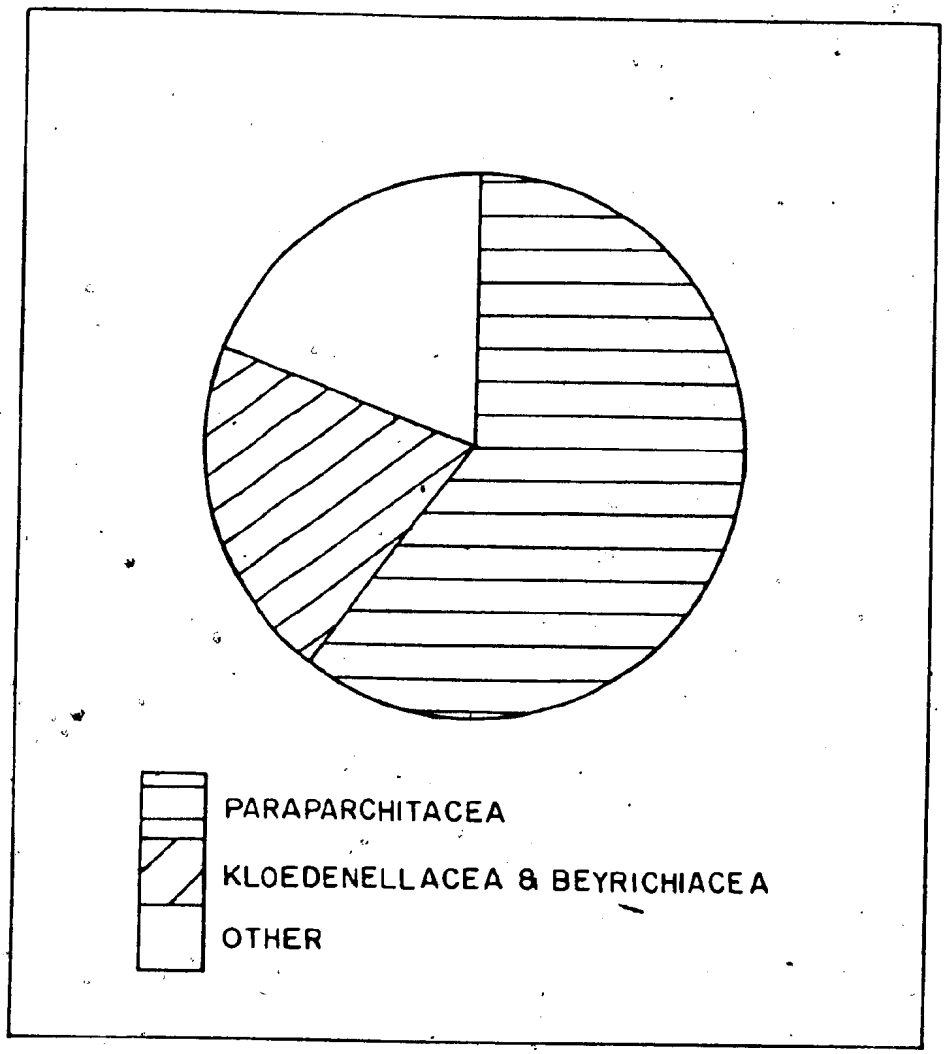
The lithology and fauna together suggest a nearshore, predominantly clastic, occasionally hypersaline, lagoonal environment.

An ostracode association of 8 species from 7 genera characterises this assemblage. The dominant species is the paraparchitacean *Chamishaella suborbiculata* which together with *Chamishaella* n. sp. A. constitutes 60% of the total ostracode assemblage.

The second most abundant species is the kloedenellacean *"Neokloedenella" variolata* which together with rare *Geisina* sp. and the beyrichiacean *"Copelandella"* sp. total 21% of the collected ostracodes of this assemblage. The main compositional elements of this assemblage are shown in Text-fig. 4.8. It is possible that *"Neokloedenella" variolata* is filling a similar marginal marine ecological niche to that of *Beyrichiopsis lophota* in Assemblage IV. *Geisina* is considered to be a nectobenthic ostracode adapted to marginal, brackish environments (Kremp and Grebe, 1955; Pollard, 1966, 1969) and *Copelandella* is also thought to have a similar ecological tolerance (Bless and Jordan, 1971a). Although they occur only rarely both *Geisina* sp. and *"Copelandella"* sp. are present in samples containing synsedimentary gypsum, which may suggest that they were also adapted to hypersaline environments; however due to their rarity it is impossible to determine if they are indigenous or transported.

Acratia acuta also occurs widely in this assemblage which emphasises the broad ecological tolerance of this species.

Acutiangulata aequalis exhibits a regular association with marginal or brackish environments, (Robinson, 1978), an



Text-figure 4.8 : Percentage pie chart for the main components of Assemblage V.

observation which is supported by the common occurrence of the species in this environment.

The lack of a full instar series in *Chamishaella* n. sp. A. (Text-fig. 6.26), *Acutiangulata aequalis* (Text-fig. 6.11), and *"Neohloedenella" variolata* (Text-fig. 6.15), together with a moderate valve to carapace ratio especially for *Acutiangulata aequalis*, mitigates in favour of post-mortem transport (Kilenyi, 1971). Sorting of faunas may have been erratic and associated with the high energy conditions which occasionally affected the lagoon. The high abundances of ostracodes in some samples, and complete absence in others, could be a function of post-mortem transport, but other explanations are possible. Ostracodes from samples in Assemblage V have a mean carapace size which is larger than the mean grain size of the sample in which they are found, which suggests that any post-mortem transport did not remove all of the indigenous fauna from a sample. Since ostracodes occur in samples with a range of 0-10% synsedimentary gypsum, it is not thought that the variation in abundances was directly controlled by salinity.

The low species to genus ratio would indicate that the assemblage is a low-level community composed of species that are either opportunistic or adapted to marginal environments. If the fauna was predominantly opportunistic then it would to some extent have been independent of nutrient supply, and produce large numbers of individuals very rapidly which would then climax and decline (Levinton, 1970). The main control upon ostracode occurrence is explained in terms of the amount of terrigenous mud being brought into the environment and the consequential rise in turbidity.

Episodic beach progradation into the lagoon (Knight, 1983) represents a regressive phase in the development of the lagoon and possibly, intermittently, an almost complete isolation from the marine influence. It is suggested that the influx of clastic material during the regressive phases caused greater restriction of ostracode communities than that encountered in Assemblage III.

In summary it is suggested that the ostracodes of Assemblage V were opportunistic or marginal marine species, living in a predominantly quiet clastic nearshore lagoon subject to periodic hypersalinity. The presence of ostracodes in any given sample of this assemblage is related to the stress level to which opportunist species can survive. The limits of survival may be related to the amount of terrigenous input and turbidity of the environment, whereas the occurrence of a large population may be related to either a marine influence and/or a decrease in terrigenous input.

4.7 Assemblage VI

Assemblage VI is confined to the Crabbes/Jeffreys Limestone exposed at Crabbes River Mouth and Stinking Cove. It is equivalent to Assemblage IV of Dewey (in press). The Crabbes/Jeffreys Limestone is dated as being equivalent to the lowermost part of the upper Codroy Group (von Bitter and Plint-Geberl, 1982) and the Jeffreys Village Member (Knight, 1983). The Crabbes/Jeffreys Limestone overlies the *Nodosinella* Band after a stratigraphic interval of about 100m.

The environment of deposition was marine subtidal with near normal salinity (Knight, 1983). However, the presence of synsedimentary gypsum in some of the sampled shale horizons suggests periodic hypersalinity. Stromatolitic horizons are considered to be intertidal in origin and the sun-cracked sediments at the top of the Crabbes/Jeffreys Limestone are interpreted as calcretes (Knight, 1983) which are evidence of a supratidal environment (Bernoulli and Wagner, 1971).

The associated fossils include bivalves, rhynchonellid and productid brachiopods, orthocerid nautiloids, crinoid ossicles, gastropods, bryozoans and conodonts (Bell, 1948; von Bitter and Plint-Geberl, 1982; Knight, 1983). Lithologies and fauna together suggest a subtidal to supratidal normal marine environment, subject to periodic sabkha-type evaporitic conditions indicative of an arid or semi-arid climate (Evans, 1970; Logan et al., 1974).

The subtidal to supratidal environment suggested for the Crabbes/Jeffreys Limestone is similar to that envisaged for the deposition of the Macumber-type lithologies of the lower Windsorian Stage (Schenk, 1969, 1979) and the upper Visean of Ireland (West et al., 1968).

Only 4 ostracode species representing 4 genera characterise Assemblage VI. The fact that the samples contain few individuals is a function of processing and occurrence. Since most ostracodes are in the limestones they are difficult to remove successfully in large numbers, and reliance on siliceous residues involves considerable loss of individuals in the processing of samples. Shale samples interbedded with the limestones are often associated

with synsedimentary gypsum needles, indicating that salinity may have been too high for a large population to survive.

The assemblage is dominated by *Chamishaella suborbiculata* which occurs in all samples that yield ostracodes. *Acratia acuta* is the second most abundant form, as might be expected from previous occurrences described herein. Little can be said of the ecological significance of kloedenellacean gen. et sp. nov. since only one complete specimen has been found.

The most significant species of the assemblage has been recovered from siliceous residues of the limestone units. *Gortanella* sp. is considered indicative of normal marine salinity subtidal offshore conditions (Bless, 1973b,c). The presence of a few individuals representing 5 instar stages (Text-fig. 6.3) indicates that the ostracodes present in the limestone samples are probably indigenous.

The absence of *Bairdia* from this subtidal normal marine environment is significant. A nearshore shallow subtidal environment, characterised by the presence of velate palaeocopes, but essentially lacking in *Bairdia* has been proposed by several authors (von Ameron et al., 1970; Bless and Massa, 1982; Kaesler, 1982). It is likely that the limestone portions of Assemblage VI represent such an environment.

The poor preservation of specimens derived from the shale horizons may indicate post-mortem transport, but without sufficient individuals to construct growth sequences it is difficult to be conclusive.

4.8 Assemblage VII

Assemblage VII is a composite assemblage, drawn from several low abundance, low diversity ostracode bearing shales in Woody Cove and Capelin Cove, and is equivalent to Assemblage V of Dewey (in press). The age of the assemblage is thought to be equivalent to the upper Codroy Group (Baird and Coté, 1964) and the Woody Cape Formation (Knight, 1983).

The Woody Cape Formation was deposited as a deltaic sequence with occasional marine horizons (Knight, 1983). It is probable that the ostracode bearing shale represents marine conditions of varying salinity and duration. Evidence of hypersalinity in some samples (Wo. 2, 4, 5 and 12) is provided by the presence of gypsum needles. The occurrence of algal limestones overlain by ostracode bearing shales (Text-fig. 2.11) militates for the presence of inter- to supra-tidal conditions (Hudson, 1970; Pollard and Wiseman, 1971) in the deltaic sequence. It has been shown that intertidal algal mats support species that are often indigenous to the algae, (Williams, 1969; Whatley and Wall, 1969), however this does not appear to be the case in the Woody Cove algal beds; which may be a result of the raised salinities of these environments.

The associated fauna includes brachiopods, the bivalve *Lithophaga* and gastropods. Rare conchostracans occur in samples Wo.2, 12 and 13, and are generally considered as brackish water indicators (Tasch, 1958; Tasch and Zimmerman, 1961), however their occurrence in sample Wo. 12 which also contains gypsum needles suggests a tolerance of raised salinities.

In total 11 species of 11 genera have been recovered from the samples, however many of the occurrences are of less than 5 individuals. Only *Chamishaella suborbiculata* occurs consistently. The presence of *Geisina* sp. and "*Copelandella*" suggest a brackish marginal marine environment (Pollard, 1966, 1969; Bless and Jordan, 1971a) for samples Wo.2, 4 and 5, however, the presence of gypsum needles in these samples may indicate a hypersaline marginal environment.

The rare occurrence of subtidal marine species such as *Bairdia* sp. *L.* and *Bassilerella firma* in samples CC.9 and Wo.4 may suggest that the samples are time averaged resulting in a mixed faunal assemblage indicative of more than one environment.

"*Neokloedenella*" *variolata* and *Acutiangulata aequalis* occur frequently but are not consistently present, and support the concept of a marginal marine environment. Further evidence is provided by the presence of the peracarid *Tealliocaris* which has been reported from other marginal marine environments (Peach, 1908; Schram, 1981a).

In summary, Assemblage VII represents a mixture of species that occur within marginal marine environments on a delta.

4.9 Assemblage correlations

4.9.1 Faunal similarity

The seven assemblages that have been defined are intuitively different and each exhibits a distinct association of

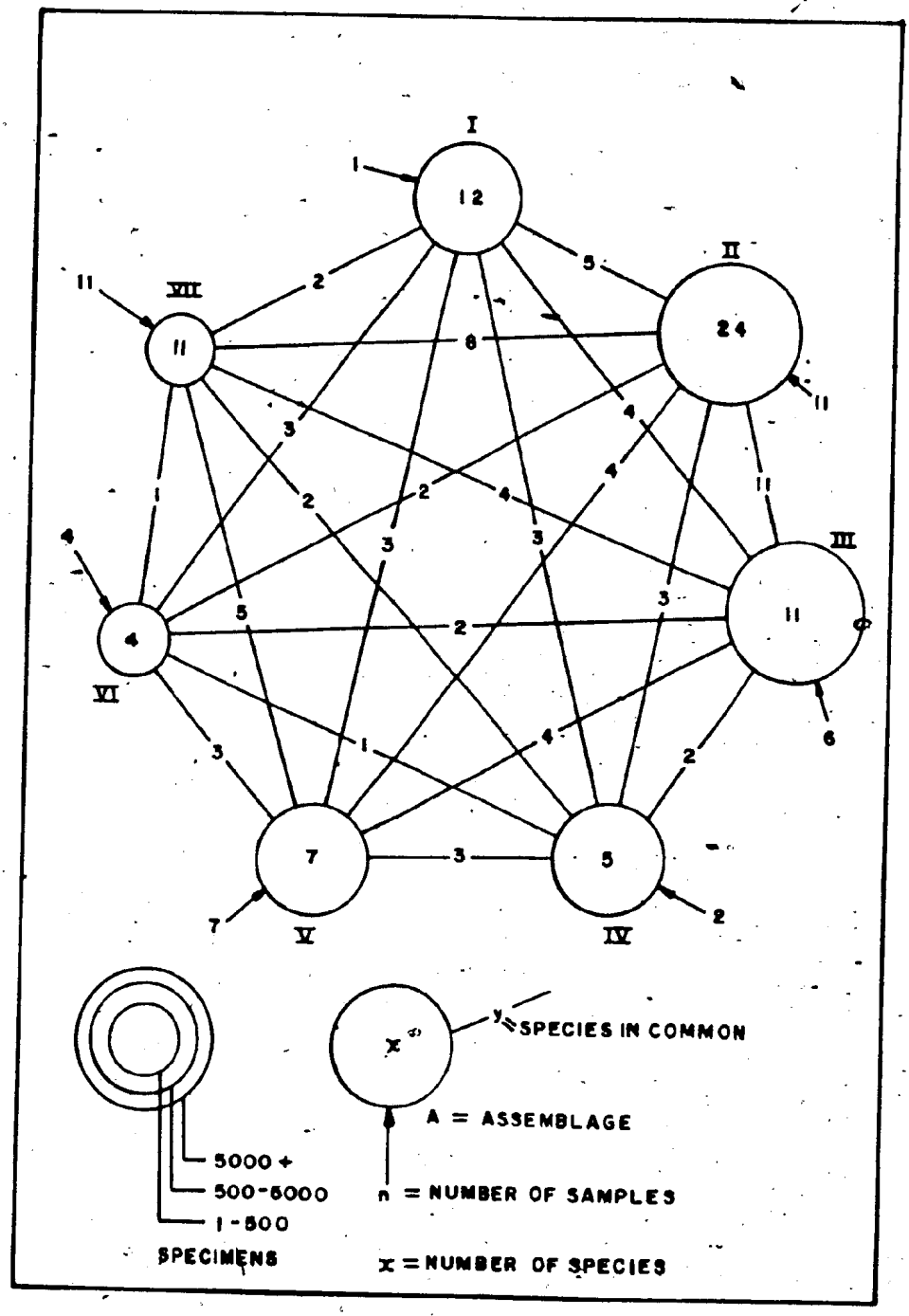
crustaceans. Attempts have been made to differentiate these assemblages using standard statistical faunal similarity indices, the results of which have not been entirely successful.

Coefficients of similarity can be used to amplify either inter-assemblage similarity or difference (Cheetham and Hazel, 1969; Raup and Crick, 1979). In this study binary coefficients based upon species presence/absence data have been used to examine assemblage correlations. There are several coefficients presently in use but for this study the Jaccard Coefficient (Jaccard, 1908) has been chosen to represent those that emphasise difference, and the Simpson index (Simpson, 1943, 1947) has been chosen to represent those that amplify similarity. These coefficients were chosen because of their common usage in the literature, facilitating comparisons.

Text-fig. 4.9 is an affinity net showing the number of species in common between assemblages, and the total number of species present in each assemblage. It also shows the relative size of the assemblage, since although the size of the population does not directly reflect the number of species present in an assemblage, it does stress the proportion of species to individuals (a factor which will be examined in the next section).

The number of samples that yield ostracodes in each assemblage is also included to show that the number of samples taken is fairly independent of number of species found, and therefore the samples can be assumed to be representative of the fauna available for sampling.

Text-figure 4.9 : Inter-assemblage species affinity net.


I
12
II
24
III
11
IV
5
V
7
VI
4
VII
11
SPECIES IN COMMON
A = ASSEMBLAGE
n = NUMBER OF SAMPLES
x = NUMBER OF SPECIES
5000 +
500-5000
1-500
SPECIMENS

Text-fig. 4.10 shows the results of the Simpson Coefficient equation as applied to the assemblages; this diagram can be related directly to the affinity net Text-fig. 4.9. The Simpson index (Simpson, 1943, 1947) is a percentage index which emphasises the inter-assemblage similitude. The Simpson index indicates, for example, that Assemblages II and III are probably subsets of the same main assemblage, however, it is implicit from the lithologies alone that the physical environments are significantly different, and would therefore be expected to support different ostracode associations. The relative abundance of species in both assemblages is an important consideration that carries no weight in the Simpson index. Further to this, species that are present in Assemblage II but absent in Assemblage III are important and yet do not affect the correlation of the two assemblages. In this study the Simpson index "overstates" faunal similarity by ignoring the composition of the larger assemblage and is therefore not a good indicator for emphasising the distinctions between subtle changes in environmental conditions.

Text-fig. 4.11 shows the results of the traditional Jaccard Coefficient equation (Jaccard, 1908). This is an exponential coefficient that emphasises small increments of difference as opposed to large increments of similarity, because the size of k can never exceed the size of B. The result of this is that correlations of similarity when k=B are directly proportional to size of A. Using Assemblages II and III as an example, even though k=B, A is still more than twice as large as B and therefore the coefficient will not exceed 0.5. All the values of the Jaccard

Text-figure 4.10 : Simpson Coefficient chart using the same net as Text-figure 4.9.

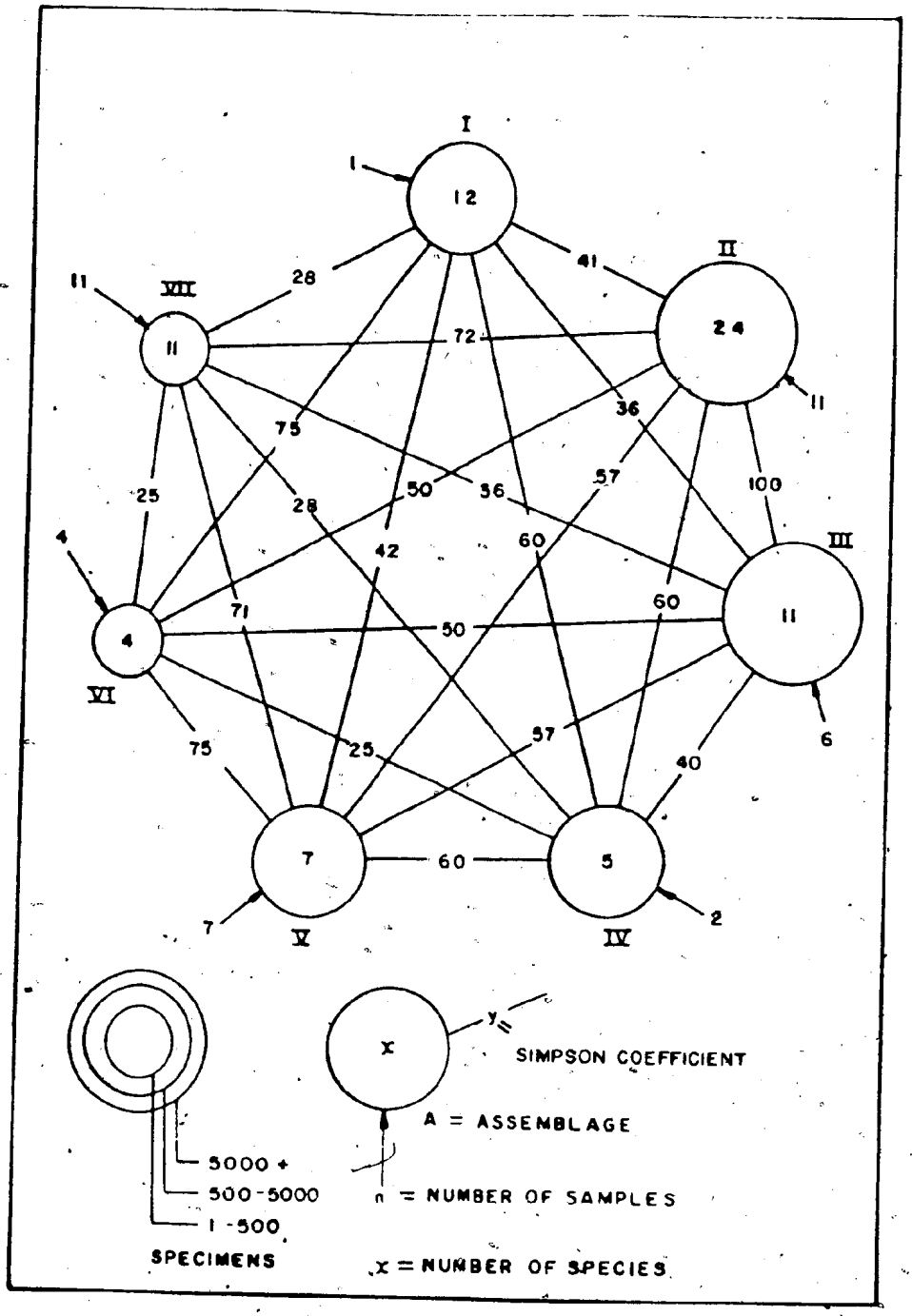
Note : Equation for the Simpson Coefficient:

$$y = 100 \frac{K}{B}$$

where K is the number species in common

B is the number of species in the smaller sample

y is the Simpson Co-efficient.


I
12
1
II
24
41
11
VII
11
28
72
36
75
25
28
50
36
57
100
4
42
60
III
11
71
50
60
VI
4
75
25
57
40
6
7
60
5
7
V
IV
2
x
y
SIMPSON COEFFICIENT
A = ASSEMBLAGE
n = NUMBER OF SAMPLES
x = NUMBER OF SPECIES
5000 +
500-5000
1-500
SPECIMENS

Text-figure 4.11 : Jaccard Coefficient chart, using the same net as Text-figure 4.9.

Note : Equation for the Jaccard Coefficient;

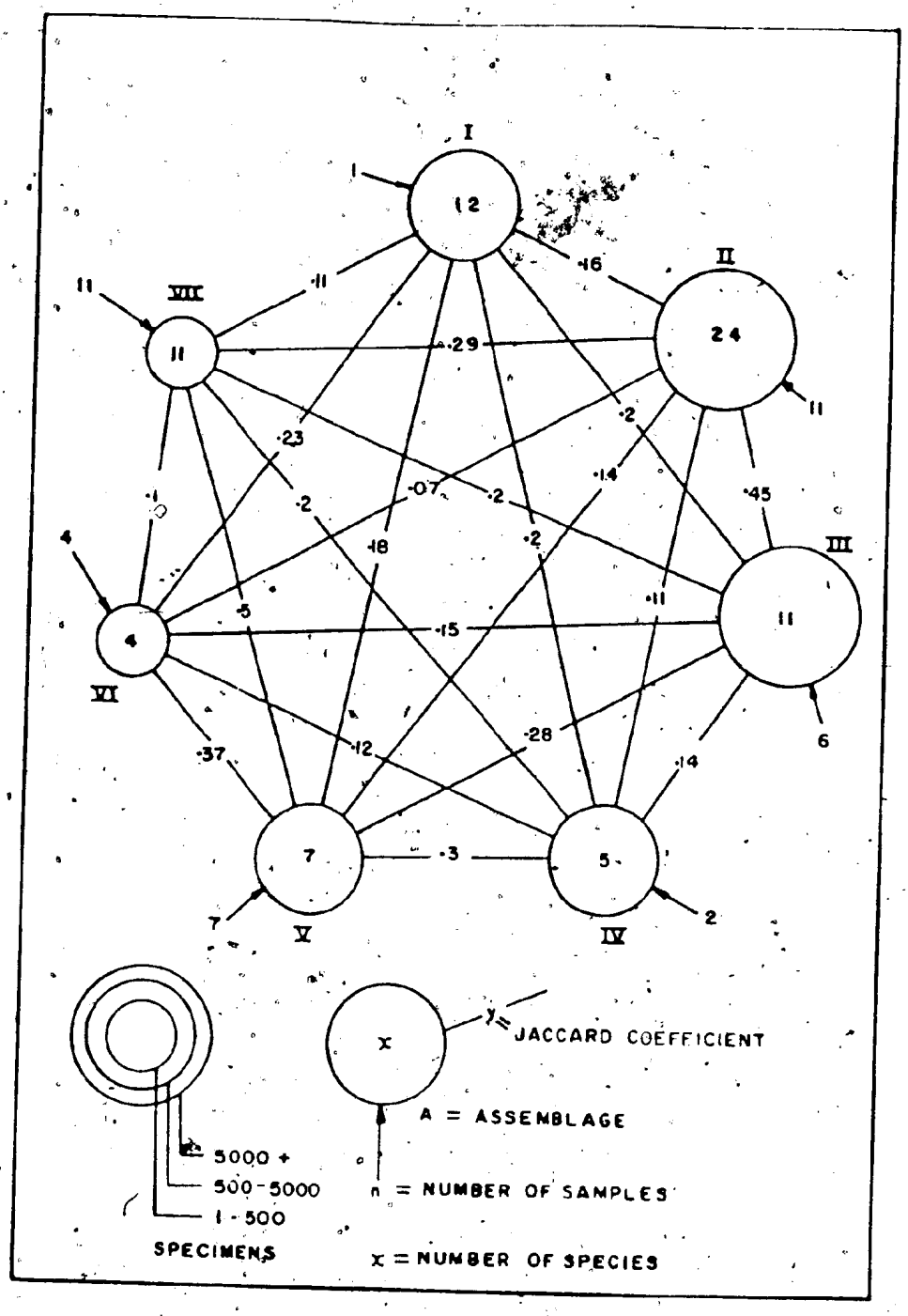
$$y = \frac{K}{A+B-K},$$

where K is the number of species in common.

A is the number of species in the larger sample.

B is the number of species in the smaller sample.

Y is the Jaccard Coefficient.


I
12
1
·16
II
24
11
·11
VIII
11
·29
·23
·2
·14
·07
·2
·45
·2
·18
·2
III
11
4
·5
·15
·11
VI
4
·37
·12
·28
·14
6
7
·3
5
7
V
IV
2
x
y = JACCARD COEFFICIENT
A = ASSEMBLAGE
n = NUMBER OF SAMPLES
x = NUMBER OF SPECIES
5000 +
500-5000
1-500
SPECIMENS

coefficient (Text-fig. 4.11) are low suggesting that there are no significant correlations between any of the assemblages.

In summary, the Simpson coefficient stresses similarities that intuitively are not strong and the Jaccard Coefficient stresses differences between assemblages to such an extent that it tends to diminish similarities that do exist.

These results are compounded by several factors:-

1. The assemblages defined are essentially environmental and comparison between them transgressed stratigraphic boundaries. The Jaccard Coefficient would tend to amplify stratigraphic replacements or difference which cannot be detected in the study due to a lack of continuous sampling through the sequences.

2. Similarities are emphasised to a greater extent by the Simpson index since several assemblages exhibit minor environmental changes which, in the case of Assemblage II warrant the definition of sub-assemblages. Neither of the coefficients are satisfactory for differentiating the effects of environmental parameters upon the assemblages because the assemblages are mostly communities which show high species dominance (see next section).

3. Both coefficients have one severe limitation in that neither of them allow for a consideration of population size, it is merely significant that a species be either present of absent. However the abundance of some species is quite significant in the definition of an assemblage.

4. They also fail to satisfy an ecological parameter in that they do not differentiate between indigenous and transported elements of the

assemblage, although it should be possible to allow for this in the construction of the statistical matrix.

4.9.2 Species diversity and dominance

The species richness on diversity of a faunal assemblage is a function of the availability of, and degree to which ecological niches within a physical environment are colonised.

In order to compare diversity of the assemblages recognised in this study, it has been necessary to employ a diversity statistic that is independent of sample population size. The rarefaction plot (Text-fig. 4.12) exhibits this property (Sanders, 1968; Antia, 1977) and allows for comparison of low and high abundance assemblages by a consideration of theoretical sample sizes. The method is interpolative, since it does not allow for extrapolation beyond the known population size. The original methodology (Sanders, 1968) tends to overstate the actual diversity and therefore the equation suggested and employed by Heck et al. (1975) and Antia (1977) was used in the construction of Text-fig. 4.12. Since the species abundance increases logarithmically and abundance of individuals increases arithmetically, rate of species increase will be diagnostic for any environment. Theoretically, a low shallow curve that levels off quite rapidly is indicative of a low diversity fauna and a high steep curve in indicative of a high diversity fauna.

The diversity of an assemblage is dependent upon several factors, the most important of which is the temporal and spatial stability of the environment (Simpson, 1964; Sanders, 1968; Johnson,

Text-figure 4.12 : Rarefaction plot of species diversity.

Note : Equation for rarefaction plot:

$$E_S = S - \sum_{i=1}^{s} \left(1 - \frac{Ni}{N}\right)^n$$

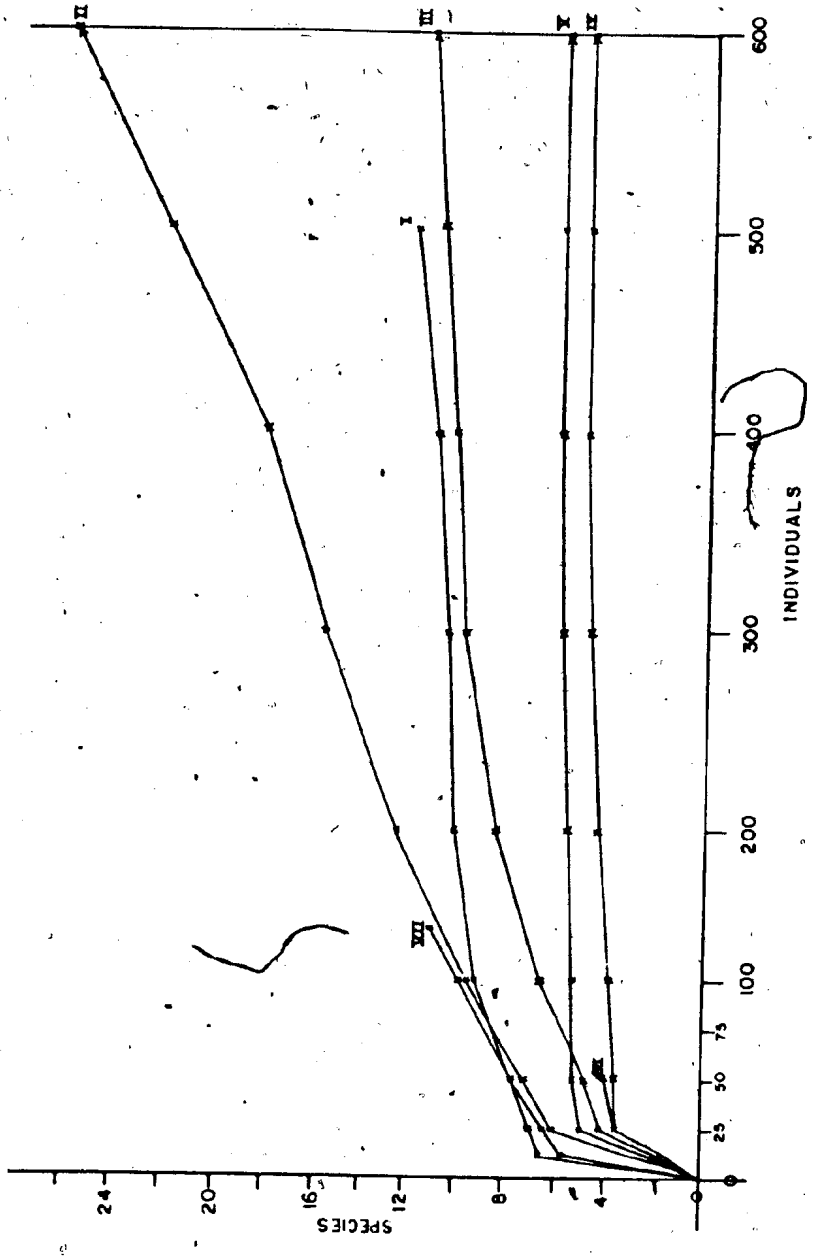
where S = number of species.

Ni = species population.

N = total population.

n = required population.

E_S = species richness for varying n


II
III
IV
V
I
VI
600
500
400
300
200
100
75
50
25
0
INDIVIDUALS
24
20
16
12
8
4
0
SPECIES

1970, 1972; Rollins et al., 1979). Highly diverse marine faunas are considered to be typical of stable offshore conditions, whereas low diversity faunas are more indicative of fluctuating nearshore environments. Temporal stability is the duration of an environment such that as a community structure devolops within a single environment, higher levels of successional organisation often exhibit species enrichment from lower levels (Rollins et al., 1979). A major control of diversity is the spatial homogeneity of the environment (Simpson, 1964). More microniches are obviously available for colonisation in a physically complex environment than in a simple physical environment and, therefore, a higher faunal diversity will result in the former than in the latter.

Post-mortem transport can adversely affect sample diversity, either by removing elements of the fauna or by introducing non-indigenous species (Wagner, 1964; Kilenyi, 1971). Death assemblages are often more diverse than life assemblages, and this must be considered when examining species richness.

Time averaging of samples can also result in an anomalous diversity by including taxa from different environments in too wide a sample horizon (Donahue and Rollins, 1974).

With these parameters in mind it is possible to examine the relationships between the rarefaction curves (Text-fig. 4.12) and the temporal and spatial stability of the physical environments proposed to support each of the assemblages.

According to Text-fig. 4.12, Assemblages II and VII exhibit the highest diversity and Assemblages I, III, IV, V and VI are lower diversity faunas. This indicates that there are several

anomalies between the observed and expected diversities, most of which are due to sampling or processing problems.

Based upon environmental analysis, Assemblage I has been suggested as occurring in the most stable offshore marine environment and yet it only shows the third highest diversity (Text-fig. 4.12) whereas it should be expected to display one of the highest. There are two main reasons for this apparent anomaly. These factors are a function of the diversity of Assemblages II and VII. On the basis of its marginal marine, predominantly brackish environment Assemblage VII would be expected to exhibit a much lower diversity than the observed value (Wagner, 1964; Kilenyi and Allen, 1968; Keen, 1977). It is likely that time averaging of samples from Assemblage VII is responsible for the higher diversity of the fauna. If the sampling horizon was too wide it is possible that minor environmental changes with slightly different faunas could have been combined in a single sample. It is also probable that since the diversity level shown represents the assimilation of data from all samples within Assemblage VII that different types of environmental communities are being combined within the single deltaic environment suggested for Assemblage VII, and giving a false impression of true diversity.

Both the observed and expected diversities of Assemblage II are high, although the fact that the assemblage is significantly more diverse than assemblage I is anomalous. The reason for this may be related to the environmental spatial heterogeneity for the two assemblages. Assemblage I is derived from a stable offshore environment whereas Assemblage II comes from a

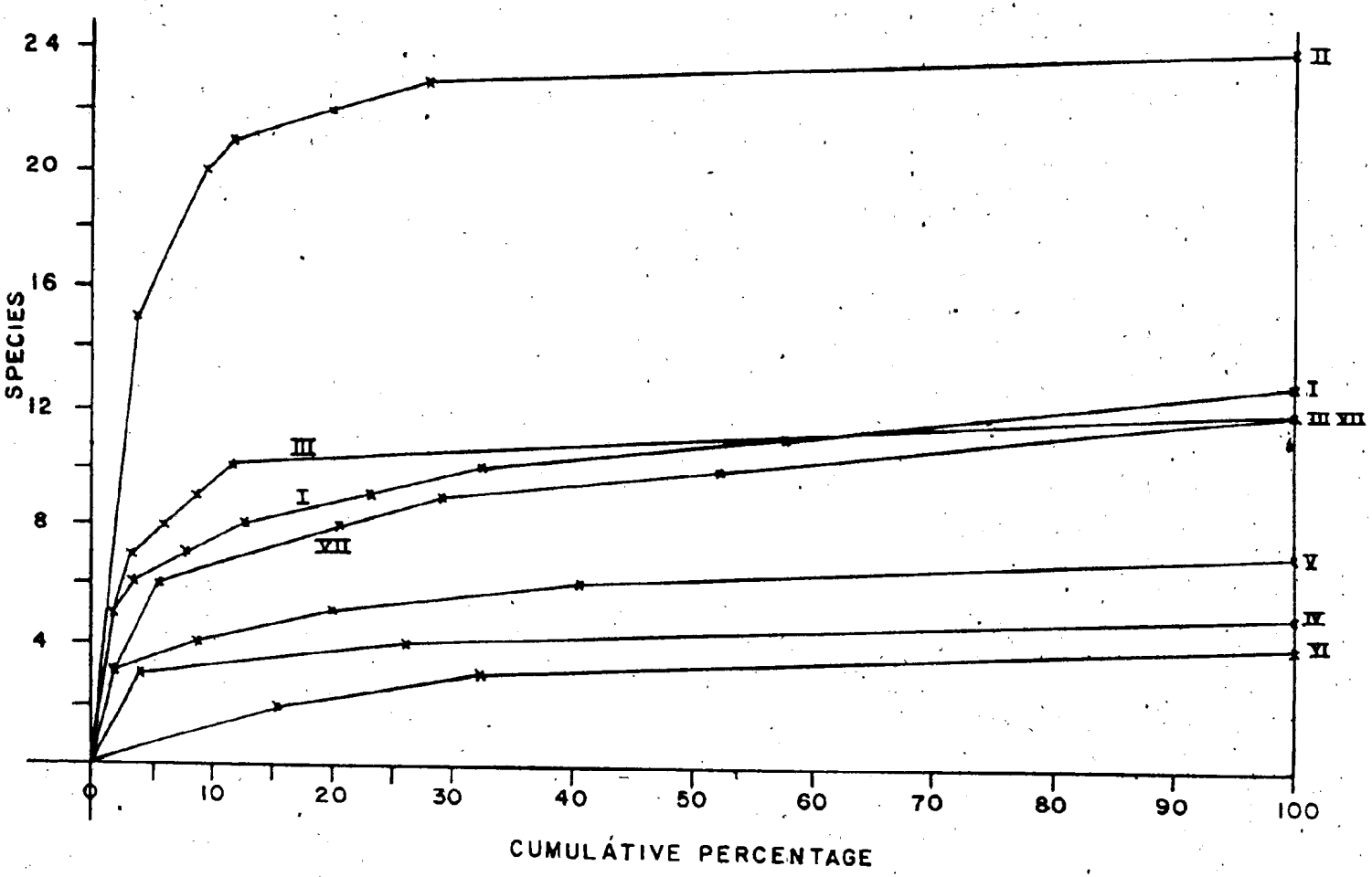
physically complex environment consisting of a drowned karstified topography, associated with bioherms (Dix, 1981). The physical environment of Assemblage II has a much greater spatial heterogeneity than that of Assemblage I, involving the availability of many differing microniches and offering a much greater degree of shelter, which would result in a high diversity fauna.

One of the other major anomalies of Text-fig. 4.12 is the very low diversity of Assemblage VI. Being derived from a subtidal hollinellid dominated environment, the assemblage would be expected to display a much greater diversity (van Ameron et al., 1970; Sanchez de Posada, 1977). The low diversity could be a function of the rapid environmental fluctuations which would restrict species occurrence, however, it is more probable that it is a function of the sampling problems that prevented the collection of the full fauna from the limestones.

The observed diversities of Assemblages II, V and IV (Text-fig. 4.12) correlate well with the expected diversity, since each of the environments is a salinity stressed environment of low stability. Due to a stronger marine influence Assemblage III shows the highest diversity of these three assemblages. Assemblage IV, on the other hand, exhibits the lowest diversity of the three assemblages due to the almost total dominance of the association by two species.

All the assemblages exhibit species dominance to some degree and this has a direct effect upon species richness. Text-fig. 4.13 is a relative dominance plot based upon species

Text-figure 4.13 : Cumulative percentage plot of species dominance.


24
20
16
12
8
4
SPECIES
0
10
20
30
40
50
60
70
80
90
100
CUMULATIVE PERCENTAGE
II
I
III VIII
V
IV
VI
III
I
VII

richness. Text-fig. 4.13 is a relative dominance plot based upon species number increase in relation to the cumulative percentage of the assemblage. The height of the dominance curve is related to the number of species present and the point at which it levels off is a function of the dominance. Strongly dominated assemblages will therefore display low curves that flatten out very quickly.

Assemblages II - VII are all dominated by species of the Paraparchitacea, whereas Assemblage I is dominated by the combined effects of the Bairdiinae and the kirkbyacean palaeocopes (Text-fig. 4.3). Assemblages II - VII were subject to physiological stress caused by raised or fluctuating salinities. Physiological stress is considered to be any factor that restricts the occurrence of a species. In this study, depth, salinity and turbidity are the main contributors to physiological stress.

Due to the inability of less eurytopic species to tolerate stressed environments, niche space will be available for opportunistic species to dominate a faunal assemblage. The dominance of an assemblage by opportunistic species indicates that an environment is governed by physical (allogenic) and not biological (autogenic) factors (Levinton, 1970; Rollins et al., 1979). *Chamishaella suborbiculata* dominates all assemblages except Assemblages I and IV. The degree to which the species is dominant is thought to be an indication of the physiological stress level of the environment. Krutak et al. (1980) demonstrated that a lower diversity, more strongly dominated fauna is produced in a typical nearshore patch reef environment that becomes subjected to physiological stress in

the form of an influx of terrigenous mud. The biohermal environment of Sub-assemblage IIA was primarily subjected to salinity pressures as evidenced by the absence of corals, crinoids and foraminiferids, and it is likely that the dominance by C. *suborbiculata* is a reflection of this fact. A secondary stress parameter is introduced when terrigenous mud adversely disrupts the environment resulting in the almost exclusive appearance of C. *suborbiculata* in Sub-assemblage IIB thus supporting the arguments of Krutak et al., 1980; and Haack and Kaesler, 1980.

Assemblage III also exhibits the effects of terrigenous mud influx and fluctuating salinities by the dominance of C. *suborbiculata* and Text-figs. 4.5 and 4.6 exemplify this relationship between adverse physical conditions and the abundance of an opportunistic species.

Assemblage IV is dominated by *Paraparchites* sp. aff. *P. kellettae* and the kloedenellacean *Beyrichiopsis lophota*. This apparent double dominance may indicate that the species occupy slightly differing niches. It is interesting to draw parallels between the dominant species of Assemblage IV and the domination of Assemblage I by *Bairdia* sp. *L.* and *Kirkbya* n. sp. A. The details of these parallels will be discussed in section 4.10.

To summarise; the diversities of most assemblages are low due to effects of physiological stress. This conclusion is supported by the strong dominance by an opportunistic species, that most assemblages exhibit.

It is also concluded that whilst rarefaction plots allow the comparison of variably sized assemblages, it is important to consider the controlling factors of the rarefaction curves before interpreting the suggested relationships.

4.10 Aspects of community structure

Attention is given to aspects of community structure such as trophic levels, niche occupancy and controls upon the overall size of specimens. These factors are of importance in the interpretation of the synecology of all the assemblages, and aid in an understanding of ostracode distribution within the environments of the Maritime Basin.

4.10.1 Nutrient supply and trophic levels

The crustaceans of the defined assemblages are low level consumers within the total biomass of each environment.

The peracarids are considered to be scavengers (Schram, 1981a) and the ostracodes are a mixture of non-selective detrital scavengers and filter feeders (Cannon, 1927, 1933; Elofsen, 1941; Tevesz and McCall, 1976; Keen, 1977).

By analogy to the studies on Recent ostracodes (Cannon, 1927, 1933); Adamczak (1969) has considered that many palaeocopes and the Kloedenellidae (sensu Adamczak, 1969) were filter feeders, whereas the bairdiids and bairdiocyprids were probably detritus feeders. The distinction is made on the basis of the comparitive morphology of the ventral margins of Recent filter feeders and detritus feeders. Adamczak (1969) considers the

presence of a ventral overlap precludes the possibility of filter feeding. The discovery of Cambrian phosphatocopine ostracodes that lack a ventral overlap, but possess preserved appendages that were adapted to filter feeding (Muller, 1979) support Adamczak's theory.

Paraparchitacea possess a well defined inner lamella and, according to this study (Pl. 16) and Sohn (1971), a ventral overlap is not uncommon, suggesting that the Paraparchitacea were detritus feeders after the same fashion as the Bairdiidae.

The peracarid *Bellocaris* indicates that nutrient supply in Sub-assemblage IIB was high, since specimens of *Bellocaris* are often found in groups, suggesting that they were collecting around a food source. Conversely *Tealliocaris* in Assemblage III indicates a low nutrient level since specimens are more random in their occurrence suggesting that they had to forage more widely for food.

The suggestion of a high nutrient supply in Sub-assemblages IIA and IIB is supported by the abundance of filter-feeding groups, e.g. brachiopods, bivalves and bryozoans (Walker and Bambach, 1974). Filter feeders are very susceptable to variations in turbidity, and the influx of large quantities of terrigenous mud would have an extreme effect upon them. This then explains the very low faunal diversity associated with Sub-assemblage IIC. Using this information the dominant ostracode, *C. suborbiculata* in Sub-assemblage IIC is suggested to be an opportunistic detritus feeder, thus relatively independent of turbidity fluctuations.

In summary, it is suggested that eurytopic detrital feeders will be able to withstand wide ranges of nutrient supply and physical fluctuation, whereas filter feeders will tend to be

susceptable to turbidity of the environment.

This then leads to the conclusion that stenotopic detrital or filter feeders will give important information with regard to the physical environment whereas eurytopic detritus feeders will be ubiquitous, and eurytopic filter feeders will be indicative of low turbidity conditions.

4.10.2 Niche occupancy and competition

Within the assemblages described in this study there are certain species or species groups for which microniche habitats have been, or can be suggested. There are also indications of competitive relationships between some species groups.

Three microniche habitats are postulated, however these do not represent all possible microniches. The microniche habitats are interstitial, vagrant benthic and nectobenthic.

Polycope n. sp. A. is suggested to be an interstital form by analogy to Recent cave dwelling forms of *Thaumotocypris* (Danielopol, 1976, 1980) and by reference to observations of the life habits of *Polycope orbicularis* (Elofson, 1941). *Polycope* n. sp. A. exhibits its greatest abundance in assemblage IIB where availability of shelter was greatest and where interstitial habitats were most stable.

Bless and Massa (1982) suggest that *Paraparchites* may be interstitial in intertidal environments, however the thick shelled carapace may be more easily related to an epibenthic habitat. Henningsmoen (1965) suggests that the dorso-posterior spines of

some paraparchitaceans may be buoyancy regulators that imply a nectobenthic lifestyle. It is suggested herein that the thick shelled carapace (together with buoyancy regulators?) in some species suggests a vagrant benthic habitat.

Ferguson (1962, 1974) suggests an inverse relationship between the occurrence of *Paraparchites* and the occurrence of *Bairdia* which is also thought to have been a vagrant benthic genus (Kornicker, 1961). It is possible that the stenotypic genus *Bairdia* was more suited to stable offshore conditions (e.g. Assemblage I) and that the eurytopic genera of Paraparchitacea could not compete with *Bairdia* in those environments. The ecological tolerance of the Paraparchitacea, however, allowed this group to inhabit and dominate environments that were inhospitable to *Bairdia*. Therefore physiological stress would have restricted the occurrence of *Bairdia* and lack of competitive ability would have excluded the paraparchitaceans from *Bairdia* dominated environments.

Other groups that show inverse relationships are the Kloedenellacea and the hollinomorph and kirkbyacean palaeocopes which show a serial replacement from supratidal to subtidal environments respectively. Several authors have suggested nectobenthic lifestyles for the Kloedenellacea (Kremp and Grebe, 1955; Pollard, 1966, 1969) and the hollinomorph palaeocopes (Bless, 1968, 1973b; Sanchez de Posada and Bless, 1971). The kirkbyacean palaeocopes are thought to have been benthic (Bless, 1973a). In the most stable offshore environment (Assemblage I) *Kirkbya* n. sp. A. was very important but in more proximal environments (Assemblages IIA, IIB)

Kirkbya n. sp. A. was replaced by the kirkbyaceans *Amphissites* sp. aff. *A. centronotus* and amphissitid gen. et sp. nov. Amphissitids also show a positive correlation with the presence of youngiellaceans in Assemblage IIB and III. In very shallow subtidal environments the hollinomorph *Cortanella* sp. was the dominant palaeocope (Assemblage VI and von Ameron et al., 1970; Bless and Massa, 1982). In the intertidal to supratidal environments and environments with a low marine affinity the beyrichacean species "*Copelandella*" sp. appeared in association with kloedenellaceans. The kloedenellacean species *Geisina* sp. "*Neokloedenella*" *variolata* and *Beyrichiopsis lophota* appear to be positively related to brackish and/or hypersaline environments to the exclusion of the palaeocopes, (Assemblages IV, V, VII). This is consistent with other studies (Pollard, 1966, 1969; von Ameron et al., 1970; Bless and Massa, 1982). In Assemblage IV *Beyrichiopsis lophota* replaces "*Neokloedenella*" *variolata* as the dominant kloedenellacean. This may have been a function of substrate. *B. lophota* occurred as the dominant form in a carbonate environment whereas "*N.*" *variolata* was abundant in siliciclastic environments. The absence of *B. lophota* in the fluvially influenced carbonate environment of Assemblage III may be related to the amount of terrigenous material being added to the environment.

The Kirkbyacea then, are most indicative of subtidal environments, whereas the Hollinomorpha may characterise nearshore environments and the Kloedenellacea characterise intertidal to supratidal environments.

The peracarids also show a competitive relationship.

Bellocaris is suggested to be a stenotopic genus characteristic of nearshore environments, whereas *Tealliocaris* is suggested to be more eurytopic. The relationship between the two genera is therefore similar to that between *Bairdia* and *Paraparchites*, in as much as *Bellocaris* is restricted by its inability to adapt to adverse conditions and *Tealliocaris* is restricted by its inability to compete in a *Bellocaris* dominated environment.

To summarise, a cumulative abundance plot (Text-fig. 4.14) displays the main inverse relationships between

a. The *Bairdiinae* and the *Paraparchitacea* and

b. The *Kloedenellacea* and the palaeocopes.

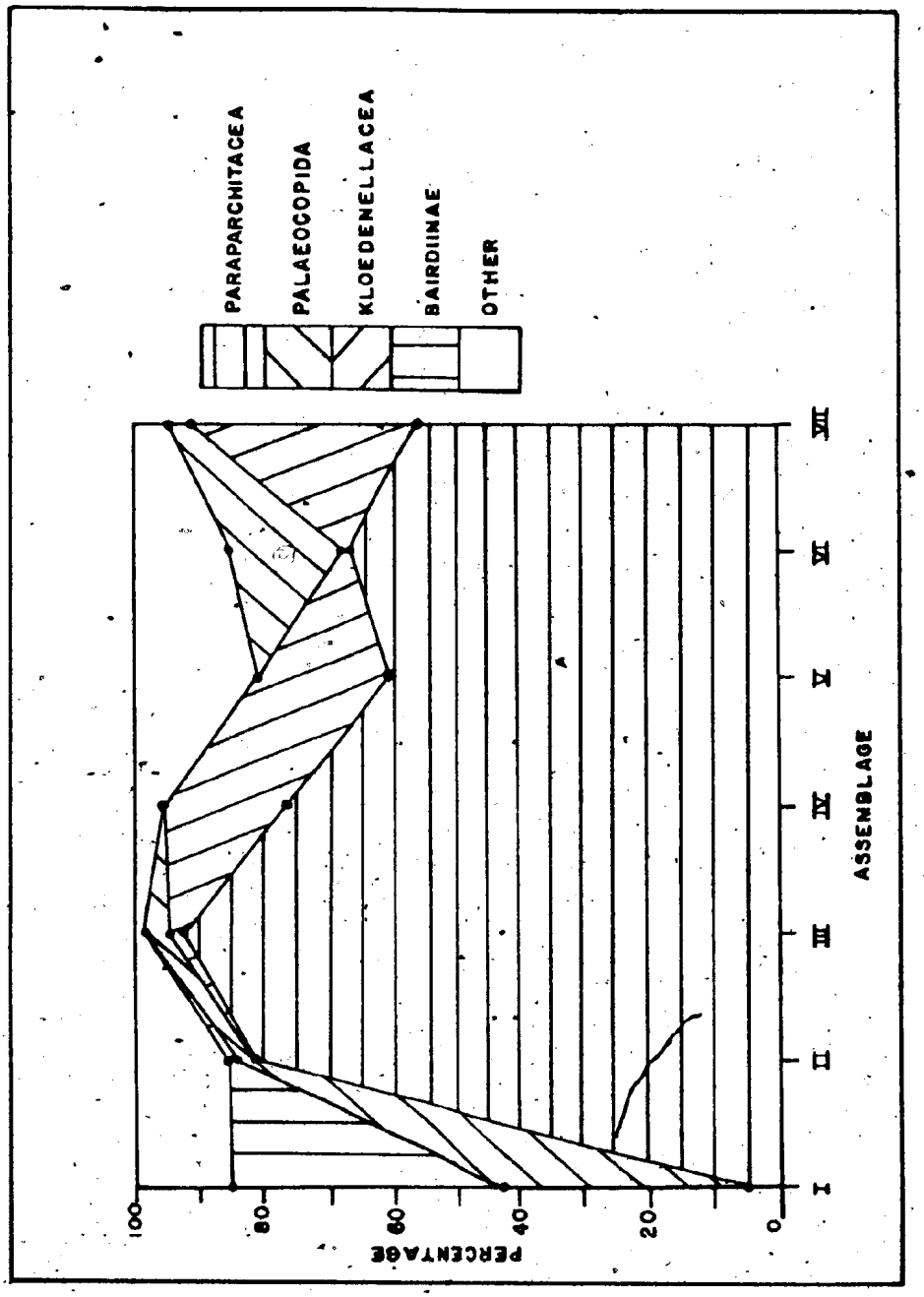
4.10.3 Species size maxima, phenotypic variation and reproductive cycles

Specific size maxima and phenotypic variation have been suggested to be functions of several possibilities, including salinity, carbonate content of the water, and substrate.

Barker (1963) and Kilenyi and Allen (1968) correlate smaller sized specimens with decreasing salinity, whereas Haskins (1969) correlates large specimens with the amount of dissolved calcium carbonate. Keen (1977) discusses these possibilities and considers them to be inconsistent, when examined on a broader scale.

Bless et al. (1981) and Bless and Massa (1982) suggest that siliciclastic substrates support smaller specimens than carbonate substrates and relate this phenomenon to the "transparency of the water column." Bless and Pollard (1973, 1975) suggest that smaller

Text-figure 4.14 : Plot of suprafamilial cumulative percentages in each assemblage.


PARAPARCHITACEA
PALAEOCOPIDA
KLOEDENELLACEA
BAIRDIINAE
OTHER
PERCENTAGE
100
80
60
40
20
0
I
II
III
IV
V
VI
ASSEMBLAGE

sized specimens in some species may be the result of growth being arrested at an earlier instar stage in harsh environments.

None of these hypotheses appear to be wholly applicable to the assemblages of this study. Although specimens are often smaller than expected by comparison to other studies they are consistently smaller regardless of substrate type. It is attractive to postulate a correlation between raised or fluctuating salinities and reduction of carapace parameters. It is unlikely, however, that the relationships are that simple since no obvious variation in specimen size occurs from species occurring in both marine and hypersaline or brackish environments. Without detailed studies it is impossible to suggest a more feasible alternative, although it is probable that the total physiological stress is an important factor governing both carapace variability and ability of a species to reach full size.

Some podocopid species show phenotypic variation by reduction of size and variation of shape in adverse environments. This phenomenon appears to be restricted to stenotopic genera such as *Bairdia*. Instars of *Bairdia* sp. *L*. are consistently higher and wider in Assemblage I (Text-fig. 6.9a) than they are in Assemblage IIB (Text-fig. 6.9b) which suggests that the reduction in size and modification of shape may be related to the physiological stress acting upon *Bairdia* sp. *L*. in Assemblage IIB. This is in accord with similar studies of phenotypic variation involving Recent *Bairdia* by Cadot and Kaesler (1973).

Other stenotopic species such as the non-dimorphic

kirkbyacean species *Amphissites* sp. aff. *A. centronotus*, (Text-fig. 6.6) *Kirkbya* n. sp. A. (Text-fig. 6.4) and the podocopid species *Acutiangulata* n. sp. A. (Text-fig. 6.2) show a large amount of carapace variability and poor instar definition. Conversely, podocopid species such as *Bassilerella* spp. (Text-fig. 6.13, 6.14) show very little variation and well defined instar groupings. This is suggested to relate to the degree of physiological stress that an environment exerts upon each of the species; such that any group of species in a given environment may be subject to different levels of stress in accordance with the ecological tolerance of each individual species. For stenotopic species well defined instar groups and low variability is indicative of low stress, whereas poor instar groupings and high variability indicates a high stress level. The loss of instar groupings may be a function of either variation of all three prime parameters of the ostracode carapace, or altered breeding cycles. Good instar clusters would be expected to be maintained by yearly breeding cycles (Szczechura, 1971) but more frequent breeding cycles resulting in overlapping generations would obscure the instar clusters (Keen, 1977), in the same manner as a variable length to height ratio, or time averaged samples. The occurrence of well and poorly clustered instar plots of different species within the same environment would militate against time averaging of samples as an explanation of the loss of instar groupings.

The lack of well defined instar grouping combined with low levels of carapace variability would suggest that eurytopic species such as the podocopid *Acratia acuta* (Text-fig. 6.10) and the

opportunistic paraparchitacean species (Text-figs. 6.23 - 6.28) exhibit continual breeding cycles and overlapping generations.

The paucity of adult-sized paraparchitacean specimens may be a function of precocious sexual development occurring at a pre-adult instar (Bless and Pollard, 1975). The lack of sexual dimorphs in species such as *Chamishaella suborbiculata* (Text-fig. 6.25) and *Shishaella moreyi* (Text-fig. 6.28) may be an indication that parthogenetic populations were developed. Parthogenesis would permit a rapid population growth which could take advantage of favourable conditions (Levinton, 1970). Sexual dimorphs can be recognised in the Paraparchitacea *Chamishaella* n. sp. A. (Text-fig. 6.23), which indicates that syngamic generations occasionally occur.

Several conclusions can be drawn from a study of phenotypic variation and growth sequences.

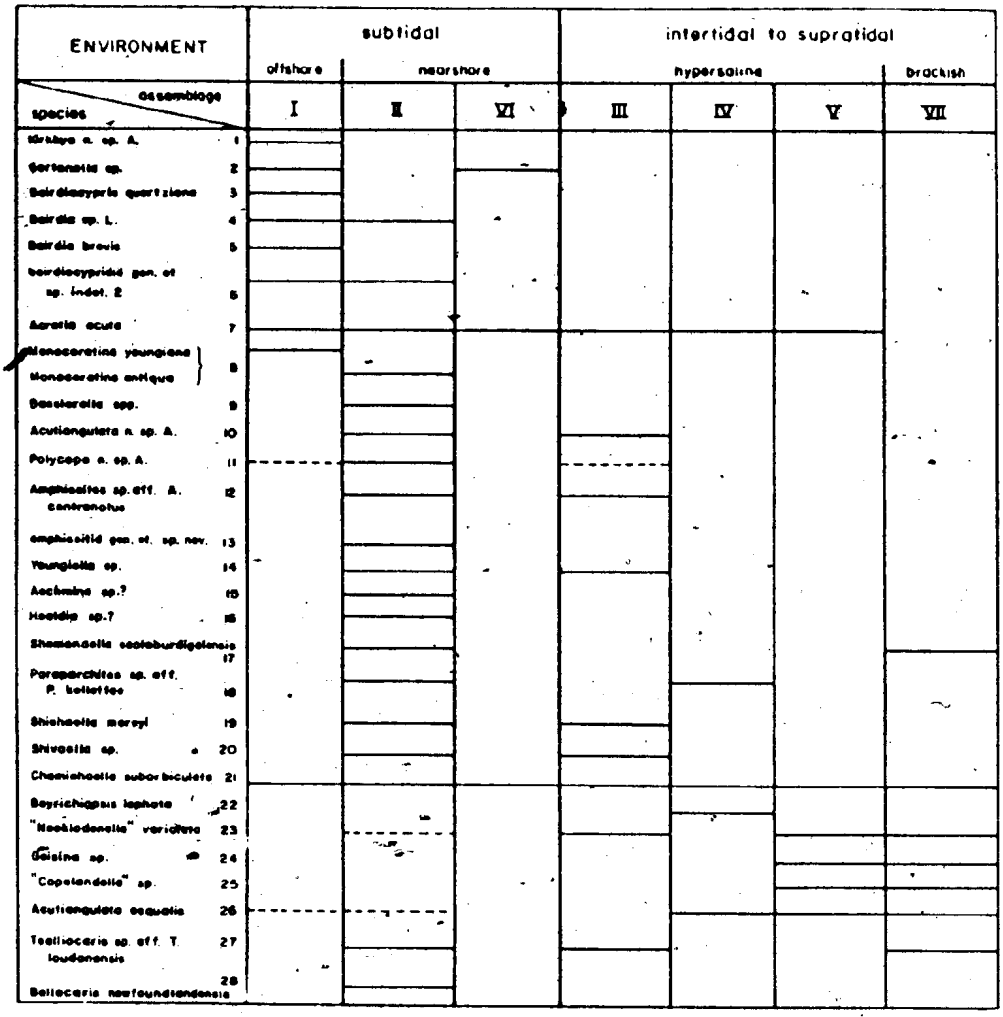
1. Most species show a reduction in size from expected values and this is thought to be a function of slightly adverse conditions of all the environments studied.
2. Stenotopic species appear to exhibit increased morphological variation as they approach their ecological limits.
3. Good instar clustering is normally a function of low variability and/or yearly breeding cycles (Szczechura, 1971; Keen, 1977).
4. Eurytopic and opportunistic species especially, tend to show low levels of phenotypic variation and loss of instar-groupings In this case the loss of instar groupings is attributed to continuous breeding cycles and overlapping generations.

5. Individual instar size maxima is a complex function of environmental factors, but the maximum size of the species may also be related to precocious sexual maturity, in some cases.

6. Parthogenetic generations may be produced by opportunistic species in order to take advantage of favourable conditions.

4.11 Conclusions

The seven crustacean assemblages defined in this study reflect the combined effects of a bathymetric gradient and variations in salinity. An outline of the ecological ranges of the most significant species (Text-fig. 4.15), clearly indicates the relationship of species occurrence to depth. Using arguments previously established herein, the plot can also be used to show the replacement relationships that occur along the depth profile. The relationships are as much a function of depth acting as a control of environmental stability as they are a function of salinity. A broad depth zonation (von Ameron et al., 1970; Bless and Massa, 1982; Kaesler, 1982) indicates that the Kirkbyacea and Hollinomorpha were typical of subtidal environments and that the Beyrichiacea and Kloedenellacea were more typical of marginal marine environments; this is substantiated by Text-fig. 4.15. *Bairdia* sp. 1., *B. brevis* and *Bairdiocypris quartziana*, together with *Kirkbya* n. sp. A. occurred in the offshore subtidal environment (Assemblage I) whereas reduced numbers of *Bairdia* together with the kirkbyacean species *Amphissites* sp. aff. *A. centronotus* and amphissited gen. et sp. nov. occurred in the nearshore subtidal environments (Assemblage II). The hollinomorph *Gortanella* sp. occurred rarely in the offshore environment, but was important in



Text-figure 4.15 : Environmental affinity diagram.

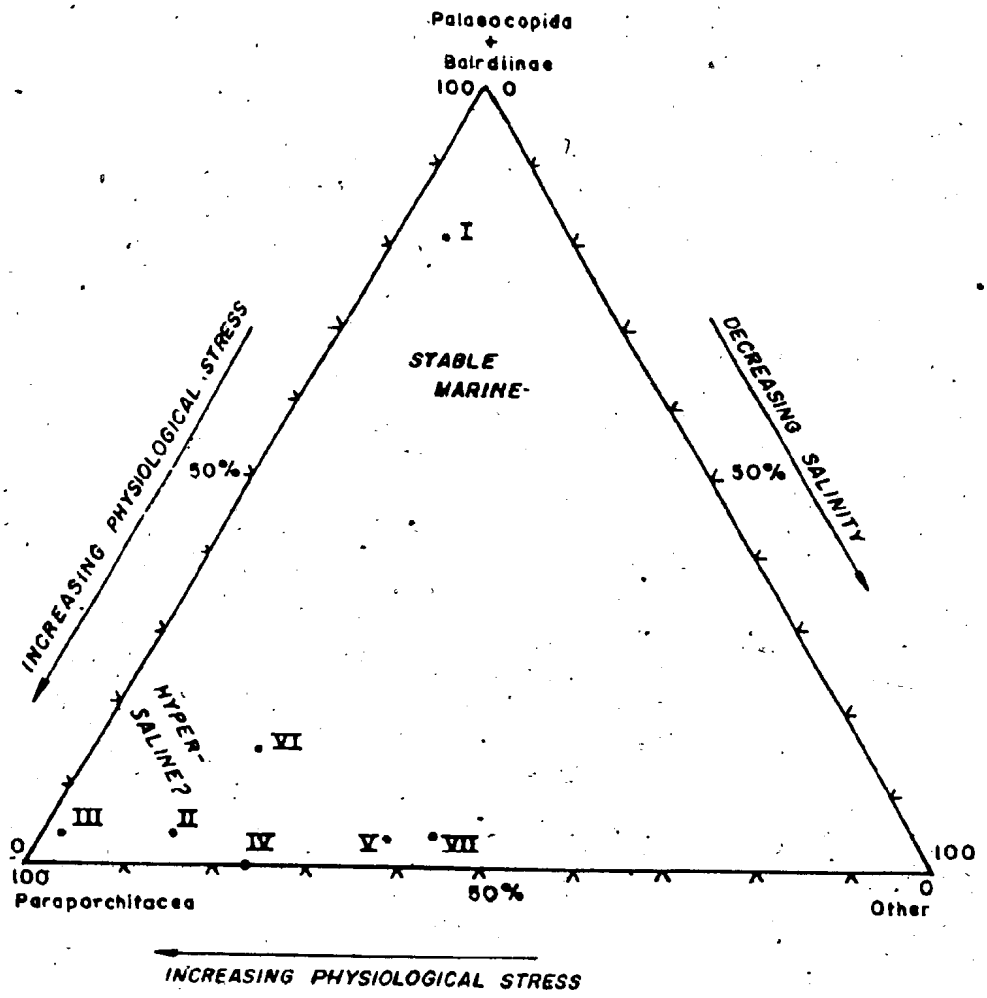
a very shallow subtidal anvironment (Assemblage VI) .

The marginal marine environments (Assemblages III, IV V and VII) were characterised by the presence of the kloedenellacean species *"Neokloedenella" variolata* and *Beyrichiopsis lophota*. Very shallow intertidal and supratidal environments (Assemblages V and VII) were characterised by the appearance of the kloedenellacean species *Geisina* sp., and the beyrichiacean species *"Copelandella"* sp..

The Paraparchitacea were ubiquitous, but show an anti-pathetic relationship with the Bairdiinae, which is a function of competitive ability and ecological tolerance.

The effects of physiological stress is expressed more by species abundance and dominance than be simple presence/absence parameters. In this study the main control of physiological stress acting upon the bathymetric zonation is salinity, such that either raised or fluctuating salinities will restrict an assemblage. The Paraparchitacea are suggested to be opportunistic eurytopic detritus feeders. They can therefore be used as an index of physiological stress.

A ternary plot of percentage Palaeocopida plus Bairdiinae : Paraparchitacea : other (Text-fig. 4.16) gives an indication of the degree of physiological stress prevailing in these assemblages. The plot is also a function of the inability of stenotopic species to withstand adverse conditions (Bretsky, 1969), since their non-occurrence leaves available niche space for the eurytopic species. An example of this is Assemblage III which is suggested as varying from brackish to hypersaline conditions and



Text-figure 4.16 : Ternary diagram of Paraparchitacea :

Palaeocopida + Bairdiinae : Other.

exhibits the highest physiological stress by the very high abundance of paraparchitacean ostracodes. Similarly an abnormally saline subtidal environment (Assemblage II) also exhibits a high stress level. Therefore the co-occurrence of these two assemblages with the same part of the ternary plot (Text-fig. 4.16) proves that the percentage of Paraparchitacea within an assemblage is not simply a function of hypersalinity.

In conclusion the crustacean assemblages display a bathymetric zonation that is modified by salinity fluctuations.

CHAPTER 5

PALAEOGEOGRAPHY

5.1 Introduction

The seven middle Carboniferous crustacean palaeoecological assemblages defined in this study are interpreted as being a reflection of physical environments produced within the tectonically evolving Maritime Basin. The environmental conditions considered typical of all the assemblages together, and for each assemblage separately, are, in the following, related to the tectonic and physiographic setting of the Maritime Basin.

The Maritime Basin is considered to have been an epicontinental extension of the northern Hercynian Ocean. Its middle Carboniferous crustacean fauna shows a strong affinity with contemporaneous western European and Russian faunas. The high degree of similarity of these faunas, and also the low similarity to contemporaneous North American and North African faunas is explained in terms of an oceanic circulation model for the Hercynian Ocean and adjacent areas.

This oceanic circulation model is based upon the application of the physical principles that define the behaviour of oceanic water masses, to a palaeogeographic reconstruction of the late Dinantian northern Hercynian Ocean and adjacent areas.

5.2 Palaeogeography of the Maritime Basin

5.2.1 General setting

During the late Devonian to middle Carboniferous,

the Maritime Basin of eastern Canada was an evolving strike-slip basin (Leeder, 1976; Bradley, 1982; Keppie, 1982; Knight, 1983) subdivided by tectonically active horst and graben structures (Howie and Barss, 1975).

Transgressive marine episodes periodically inundated the basin during the 10 million year long Windsorian Stage (Moore, 1967; Giles, 1981; Knight, 1983), resulting in an epicontinental extension of the Hercynian Ocean that lay to the south. The transgressive cycles are thought to have been eustatically controlled by variations in the size of the polar ice cap (Crowell, 1978; Giles, 1981), but their extent was also controlled by intrabasinal tectonics.

Deposition of limestones, red siliciclastics, evaporites and coals within the basin suggests an arid to semi-arid tropical environment (Bell, 1929; Schenk, 1969; Van de Poll, 1978; Van der Zwan, 1981). The presence of evaporites and carbonates suggests a low latitude, warm climatic belt with a negative precipitation budget (Evans, 1970; Drewry et al., 1974), and the co-association of red beds, coals, and evaporites is considered indicative of active tectonism (Van de Poll, 1978; Van der Zwan, 1981).

It therefore seems possible that the environments of the Maritime Basin were developed in a hot dry climate associated with seasonal runoff. The combined effects of climate, eustatic changes in sea-level and tectono-physical activity caused low temporal and spatial stability within the basin. High grade faunal communities would not therefore be expected to have been established

within this framework.

5.2.2 Environmental aspects

The Maritime Basin was composed of a series of inter-connected sub-basins that were essentially controlled by continuing activity of horst and graben structures (Howie and Barss, 1975). Transgressive pulses were superimposed on this structural profile, resulting in a complex system of subtidal to supratidal environments.

In the subtidal environments, drowned topographic highs often supported biohermal communities of the Gays River type (Giles et al., 1979) while the intervening topographic lows were typified by low-grade communities resulting in the deposition of cryptalgal laminites of the Macumber-type (Geldsetzer, 1977, 1978). At the edges of the sub-basins a complex system of coastal features developed on both high and low angle coastlines (Schenk, 1969; Dix, 1981).

Of the assemblages defined in this study only Assemblage IIA is typical of the Gays River type lithologies. Assemblage I is indicative of an offshore subtidal environment whereas all the others are representative of proximal subtidal to supratidal environments. Marine faunal environments are primarily depth related and therefore usually parallel coastlines. The type and width of the environments available for colonisation is thought to be related to tectonics (Anderson, 1971). Anderson (1971) suggests that a low tectonic regime, characterised by low palaeoslopes and

typical of stable transgressive seas can be subdivided into five major zones of model 1 :

(a) tidal flat

(b) restricted subtidal

(c) subtidal above wave base

(d) subtidal near wave base

and (e) below wave base;

whereas a high tectonic regime characterised by high palaeoslopes can only be subdivided into three major zones of model 2 :

(a) littoral complex (lagoons, beaches, deltas)

(b) open shelf above

and (c) below wave base

The environments of the Maritime Basin were characterised by a high tectonic regime. However, transgressive episodes apparently affected predominantly fluvio-clastic sub-basins with both low and high angle palaeoslopes, resulting in a combination of model 1 and model 2 environments; suggesting that inclination of palaeoslope is not simply a function of tectonic activity.

Tidal flat deposits at Fischells Brook composed of stromatolitic, laminated, mud-cracked and pelletal carbonate mudstones associated with sabkha-type evaporites; and sabkha-type evaporites that overly the Dimrock and Phillips Limestones (Geldsetzer et al., 1980) which yield Assemblage IV; correspond to environment (a) of model 1. These environments are indicative of a low angle palaeoslope.

Lagoonal deposits, such as those from which Assemblages

III and V were collected, correspond to environment (a) of model 2 as does the delta sequence from which Assemblage VII was collected. These types of environments are often indicative of tectonically rising land and continuous terrigenous influx (Anderson, 1971).

The subtidal deposits all indicate model 2 environments. Assemblage VI sediments are composed of skeletal, pelletal carbonate mudstones, gypsiferous shales and mud-cracked mudstones. It is thought that the Crabbes/Jeffreys Limestone records a regression from subtidal to supratidal environments (Knight, 1983) and therefore should represent environments (a) and (b) of model 2. Assemblage-II is indicative of a drowned high angle shoreline, and therefore represents environment (b) of model 2. Barrier deposits, such as those of the Black Point Limestone (Assemblage II subset) and Cormorant Limesone, are suggested to fringe hypersaline lagoons (Knight, 1983) and as such would also be indicative of model 2 conditions.

Shallow subtidal to supratidal deposits from which the crustacean assemblages have been derived are typical of prograding coastlines in an area of carbonate deposition where sustained clastic influx was due to tectonically rising land (Anderson, 1971; Knight, 1983).

A palaeogeographic reconstruction of the St. George's Bay sub-basin of southwestern Newfoundland (Text-fig. 5.1 in back pocket) adapted from Dewey (in press) gives a paradigmatic representation of the area as it might have been during the Windsorian Stage. Although Assemblages II and III are not strict

time equivalents of Assemblages V, VI and VII, the diagram gives an idea of the regional extent and types of environment that have yielded ostracodes in this study. It should be noted that the basin was evolving, and the reconstruction given represents the basin in its later developmental stages, when the Port au Port Peninsula had probably reached its present position (Knight, 1983).

The boundaries of the depositional area were marked in the east by the fault bounded basement high of the Long Range Mountains (Baird and Cote, 1964; Knight, 1983) and in the north by the Taconic allochthons including the obducted ophiolite slabs of the Bay of Islands complex (Williams and Talkington, 1979) (Text-fig. 5.1)

From a survey of known occurrences of Carboniferous sediments in the Maritime area (Text-figs. 1.2 and 1.4), it appears likely that much of insular Newfoundland was sub-aerially exposed during the middle Carboniferous. Intermontaine lacustrine sequences in the Deer Lake Basin (Hyde, 1979) and the presence of Windsorian carbonates and evaporites in the offshore of the Grand Banks and White Bay (Howie and Barss, 1975; Barss et al., 1979) support this conclusion. The south-west corner of the island is therefore thought to have formed the eastern boundary of the Maritime Basin. The northern and western boundaries of the Maritime Basin were formed by the St. Lawrence and the New Brunswick Platforms which, together with the Meguma Platform in the south (Howie and Barss, 1975; Schenk, 1975) resulted in a restricted southern entranceway to the Maritime Basin. The exact form of the basin was, however,

changing throughout the Windsorian stage due to the effects of strike-slip, and horst and graben tectonics (Howie and Barss, 1975; Keppie, in press). A postulated poor oceanic circulation combined with a semi-arid climate gave rise to widespread hypersalinity throughout the basin.

Two theories have been postulated for the deposition of evaporites associated with the transgressive episodes in the Maritime Basin. Schenk (1969, 1975) suggests that the evaporites produced are of subaerial origin, being deposited in inter- to supratidal sabkha environments; whereas Geldsetzer (1977, 1978) suggests that they are subaqueous in origin and deposited in stagnating subtidal environments. It is, however, likely that both models apply since in southwestern Newfoundland evidence of hypersalinity is associated with inter- to supratidal environments (Knight, 1983), whereas in some other areas hypersalinity appears to be associated with stagnation of subtidal environments (Giles, 1981).

From this it is concluded that a tectonically active basin, subject to transgressive-regressive cycles in a semi-arid climate, resulted in the establishment of a series of predominantly low level faunal assemblages. The lack of temporal and spatial stability prevented the development of high level communities, by introducing considerable physiological stress into the environments.

During the middle Carboniferous transgressive episodes flooded low lying areas resulting in wide tidal flats in some areas, whilst in other areas a steeper palaeoslope resulted in lagoonal environments and barrier complexes as well as drowned karstified

coastlines.

In the deeper subtidal areas drowned topographic highs gave rise to biohermal complexes, and intervening lows resulted in deposition of cryptalgal laminites.

Stagnation, following the transgressive episodes, resulted in hypersalinity throughout the basin. In marginal environments the hypersalinity resulted in sabkha-type environments, following the model of Schenk (1969, 1975); whereas in basinal centres evaporite deposition was sub-aqueous following the model of Geldsetzer (1977, 1978). Hypersalinity was a function of poor circulation, due to an epeiric "cul-de-sac" and low rainfall in a hot semi-arid climate.

5.3 Palaeogeography of the northern Hercynian Ocean

5.3.1 Palaeogeographic reconstruction and Oceanic circulation

During the middle Carboniferous, the Maritime Basin was an enclave of the northern Hercynian Ocean and its crustacean fauna therefore shows the greatest affinity with European faunas. In order to demonstrate the pathways necessary for this affinity a palaeogeographic model of the Hercynian Ocean and adjacent areas has been constructed (Text-fig. 5.2 in back pocket).

Based upon the palaeogeographic reconstructions of Scotese et al. (1979) and Ziegler et al., (1979) and a wind driven oceanic circulation pattern (Munk, 1950, 1955) it has been possible to reconstruct an oceanic circulation pattern for the middle

Carboniferous (Text-fig. 5.2).

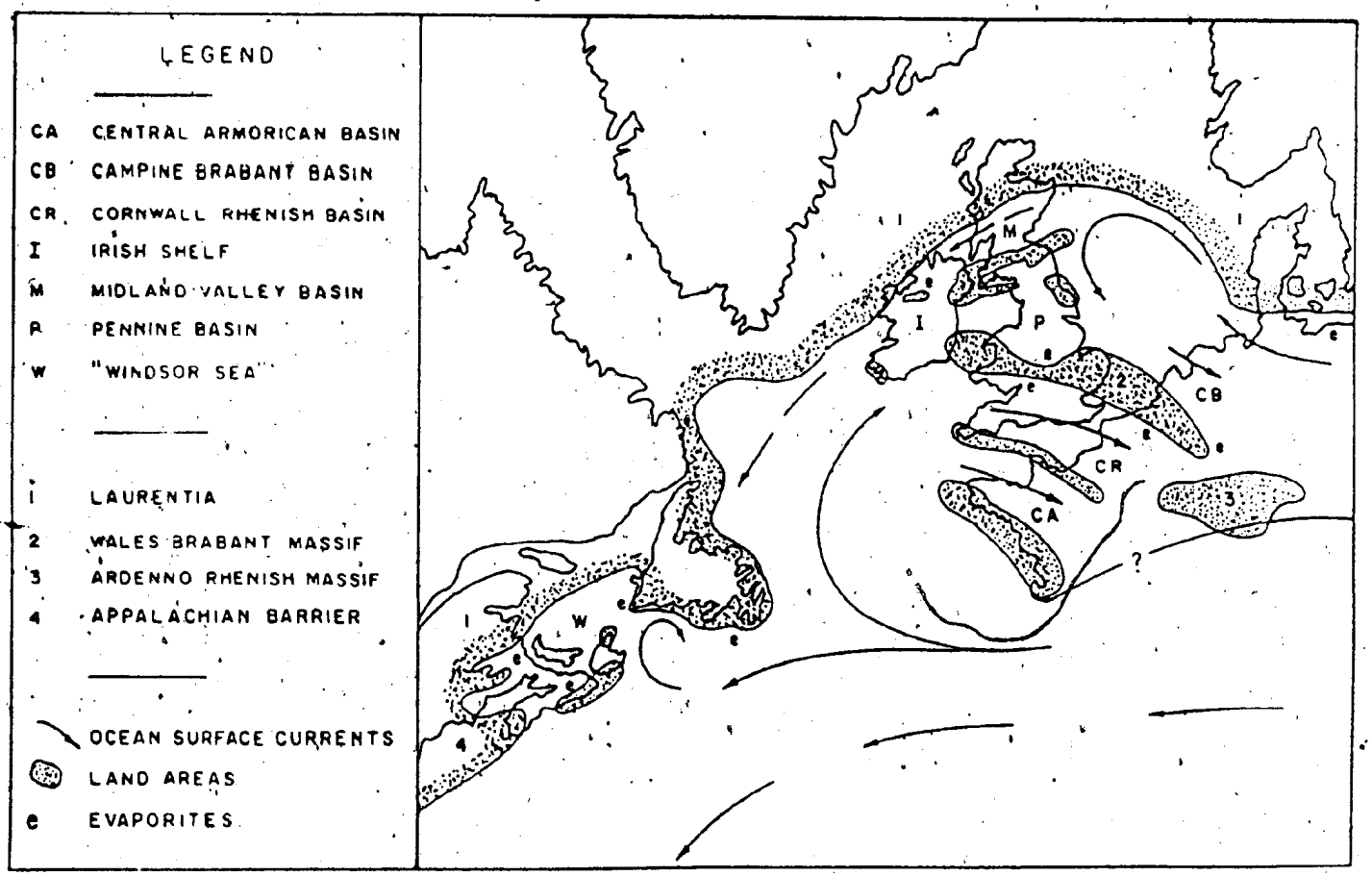
The tectonic conditions affecting the Hercynian Ocean and adjacent areas are drawn from several sources. Westward subduction is postulated in the southwestern part of Laurentia during the Mississippian Antler orogeny, as a magmatic arc to the west over-rode oceanic crust attached to north America (Speed and Sleep, 1982). In the northwestern part of Laurentia, however, extensional tectonics is suggested for parts of the Canadian Cordillera (Tempelman-Kluit, 1979). On the eastern side of Laurentia subduction in the Uralian Ocean was taking place on both the Russian and Siberian sides of the ocean (Hamilton, 1970).

The northern margin of Laurentia was essentially a stable shelf receiving carbonate and evaporite deposits (Davies, 1975).

The southern margin of Laurentia and the northern margin of Gondwanaland were colliding in a predominantly dextral strike-slip motion (Leeder, 1976; Arthaud and Matte, 1977; Lefort and Van der Voo, 1981; Badham, 1982; Dewey, 1982).

During the middle Carboniferous, South America, which formed the western edge of Gondwanaland, was subject to subduction along its entire length (Kanasewich et al., 1978; Forsythe, 1982). It is postulated that a transform fault existed between the oceanic plates to the west of Gondwanaland and Laurentia (Kanasewich et al., 1978). The continental land mass of Laurentia straddled the equator, which trended just north of Newfoundland and south of the British Isles (Irving, 1977; Scotese et al., 1979; Ziegler et al., 1979). Knowledge of the palaeoequator enables the positions of the global

Text-fig. 5.3 : Middle Carboniferous palaeogeographic reconstruction of the northern Hercynian Ocean, showing possible surface ocean currents.


LEGEND
CA CENTRAL ARMORICAN BASIN
CB CAMPINE BRABANT BASIN
CR CORNWALL RHENISH BASIN
I IRISH SHELF
M MIDLAND VALLEY BASIN
P PENNINE BASIN
W "WINDSOR SEA"
1 LAURENTIA
2 WALES BRABANT MASSIF
3 ARDENNO RHENISH MASSIF
4 APPALACHIAN BARRIER
OCEAN SURFACE CURRENTS
LAND AREAS
e EVAPORITES
I
M
P
CB
CR
CA
W
?

wind belts to be established. Palaeo-oceanic circulation patterns are not only a function of wind driven currents that are subject to the Coriolis effect, producing geostrophic flow due to rotation of the earth (Munk, 1950, 1955; Drake et al., 1978), but also to the size and positioning of the continental land masses (Luyendyk et al., 1972).

The reconstruction provided by the assimilation of these data allowed the plotting of probable ocean gyres. In the northern hemisphere an eastward flowing circum-polar current and clockwise ocean gyres are deduced based upon the trend of the Uralian Ocean, lack of a polar land-mass and major wind belts. In the southern hemisphere anti-clockwise gyres are postulated.

The majority of the Hercynian Ocean lay to the south of the equator, and, under the influence of south-east trade winds it is likely that an eastward flowing equatorial current would flow along the northern margin of the ocean, whereas a weaker westward current would flow along the southern edge. The latter current would be fed by the northeastward flowing arm of the South American current.

Since the Doldrums straddle the modern day equator, it is suggested that similar conditions during the Dinantian produced a counter equatorial current flowing against the westward flowing feeder from the Uralian Ocean (Text-figs. 5.2 and 5.3). This is consistent with evidence derived from the distribution of goniatites, brachiopods and corals (Ramsbottom, 1970; Bless and Winkler Prins. 1972; Poty, 1980). The flow in this area was

probably more complicated than indicated since it is probable that the dominant currents were shelf currents, which are governed not only by wind direction but also coastal physiography (Csanady, 1981).

Using this palaeogeographic model it is possible to explain the similarities of the European and Maritime Basin crustacean faunas.

5.3.2 Faunal relationships of the Maritime Basin with adjacent areas

The Hercynian Ocean, of which the Maritime Basin was an embayment, was almost east-west trending and therefore within a single climatic belt. This fact combined with the tectonically active sub-basinal nature of northwestern Europe (George, 1958; Ziegler, 1981) and the transgressive-regressive cycles that affected the area (Ramsbottom, 1973, 1979) led to the presently noted widespread occurrence of evaporites (West et al., 1968; Bless et al., 1981). The environmental setting of northwestern Europe and the Maritime Basin were therefore quite similar and a strong affinity between their respective faunas is to be expected.

The circulation pattern of currents in the northern Hercynian Ocean (Text-fig. 5.3) further suggests an affinity of Russian, European and eastern Canadian faunas. During the summer months the south-east trade winds would migrate northward and therefore strengthen the counter equatorial current, whereas in the winter months the feeder from the western Uralian Ocean would be stronger. It is reasonable therefore to expect a high degree of

mixing between the faunas of the Uralian Ocean and those of the Hercynian Ocean.

It is further suggested that patterns of endemism are a function of continental positioning and barrier distribution (Valentine, 1971). A narrow equatorial ocean dotted with several land areas, subject to seasonal wind variations, and a predominantly east to west trending ocean current would be a good conduit for faunal transfer. The extensive development of epicontinental seas would also favour faunal transfer.

An analysis of taxa occurring in the Maritime Basin shows that, of 34 species present, at least 13 of them show affinity to European taxa and 6 of those show an affinity to Russian faunas (Text-fig. 5.4). This is consistent with the ideas of Einor et al. (1972), who postulated a strong faunal connection between Russia and western Europe during the Viséan. Two species that may show an affinity to European faunas are *Gortanella* sp. and *Shishaella moreyi*. If *Gortanella* sp. can be synonymised with *Hollinella (Keslingella) longispina* either as *Gortanella longispina* or *Hollinella (Keslingella) radiata* (see Chapter 6) then another strong European affinity will be established. Also, if *Shishaella moreyi* can be shown to be part of a continuous morphological series from *Shishaella williamsae* to *Shishaella* sp. aff. *S. porrecta* a further European link would be demonstrated. Since other Carboniferous species of *Polycope* have only been described from Europe, it is also thought that the presence of *Polycope* n. sp. A. in the Maritime assemblages is indicative of a European affinity.

Of the 7 species that show an affinity to North

Text-fig. 5.4 : Chart showing affinities of palaeobiogéographically significant species.

Species \ Affinity	Russia (Donetz Basin)	Europe (Northwestern Basins)	Eastern Canada incl. (endemic)	North America (Mid-Continent)
Gortanella sp.	?	?		?
Bairdia sp. L.				
Bairdia brevis				
Baldiacypris quartziana				
Acratia acuta				
Acutiangulata aequalis				
Bassterella firma				
Bassterella obesa				
Monoceratina antiqua				
Monoceratina youngiana				
"Neokloedenella" variolata				
Beyrichiopsis cornuta				
Paraparchites sp. aff. P. kellettae				
Chamishaella suborbiculata				
Shemonaella ecotoburdigalensis				
Shishaella moreyi		?		
Shivaella sp.				
Polycope n. sp. A.				
Tealliocaris sp. aff. T. loudonensis				
Bellocaris newfoundlandensis				
amphissitid gen. et sp. nov.				
"Copelandella" sp				
Beyrichiopsis lophota				
gen. et sp. indet. 1				
gen. et sp. indet. 3				

American Mid-Continent faunas (Text-fig. 5.4), 3 of them also show an affinity to European faunas. The low affinity with North American faunas is suggested to be a function of the Appalachian barrier and circulation of ocean currents away from the Mid-Continent in a northward direction (Text-fig. 5.2).

With respect to the Maritime Basin itself there appear to be 6 endemic species, of which two are indetermined species, and one is a new genus and species. It should be noted that of these species *Beyrichiopsis lophota* is very similar to *Beyrichiopsis plicata* which is widestread in Russia, Europe and North America.

There is a lack of species affinity between North African faunas (Omara and Gramman, 1966; Bless and Massa, 1982), and those of the Maritime Basin. According to Bless and Massa, (1982) these faunas should be related to European assemblages, however the large number of new species described from North Africa also suggests a high degree of endemism.

The above outlined dispersal of species was due to the transfer of naupliar larvae in surface ocean currents (Neale, 1964; McKenzie, 1968). Since many of the species discussed are benthic or nectobenthic and much of the Hercynian Ocean's northern coastline consisted of epicontinental shelves, faunal transfer would have been facilitated by the migration of larvae in shelf currents. If a larva survives for up to six weeks and is transported in a current of 0.5km/hour it could travel a maximum of 500km (Scheltema, 1977); thus they could easily cover the postulated distances in 2 or 3 generations. It is also expected that the most eurytopic species would have the greatest geographic ranges

(Scheltema, 1977); an expectation which also agrees with the results of this study.

5.4 Summary

Of 34 species of middle Carboniferous crustaceans described from the Maritime Basin of eastern Canada at least 38% show an affinity with north-west European faunas and 50% of these show an affinity with Russian faunas.

Only 20% of the total fauna shows any relationship to North American assemblages and 42% of these also show an affinity with northwestern Europe. These relationships are attributed to the tectonophysical and climatic setting as well as the palaeo-oceanic circulation patterns.

CHAPTER 6

SYSTEMATICS

6.1 Introduction

6.1.1 Suprafamilial taxonomy

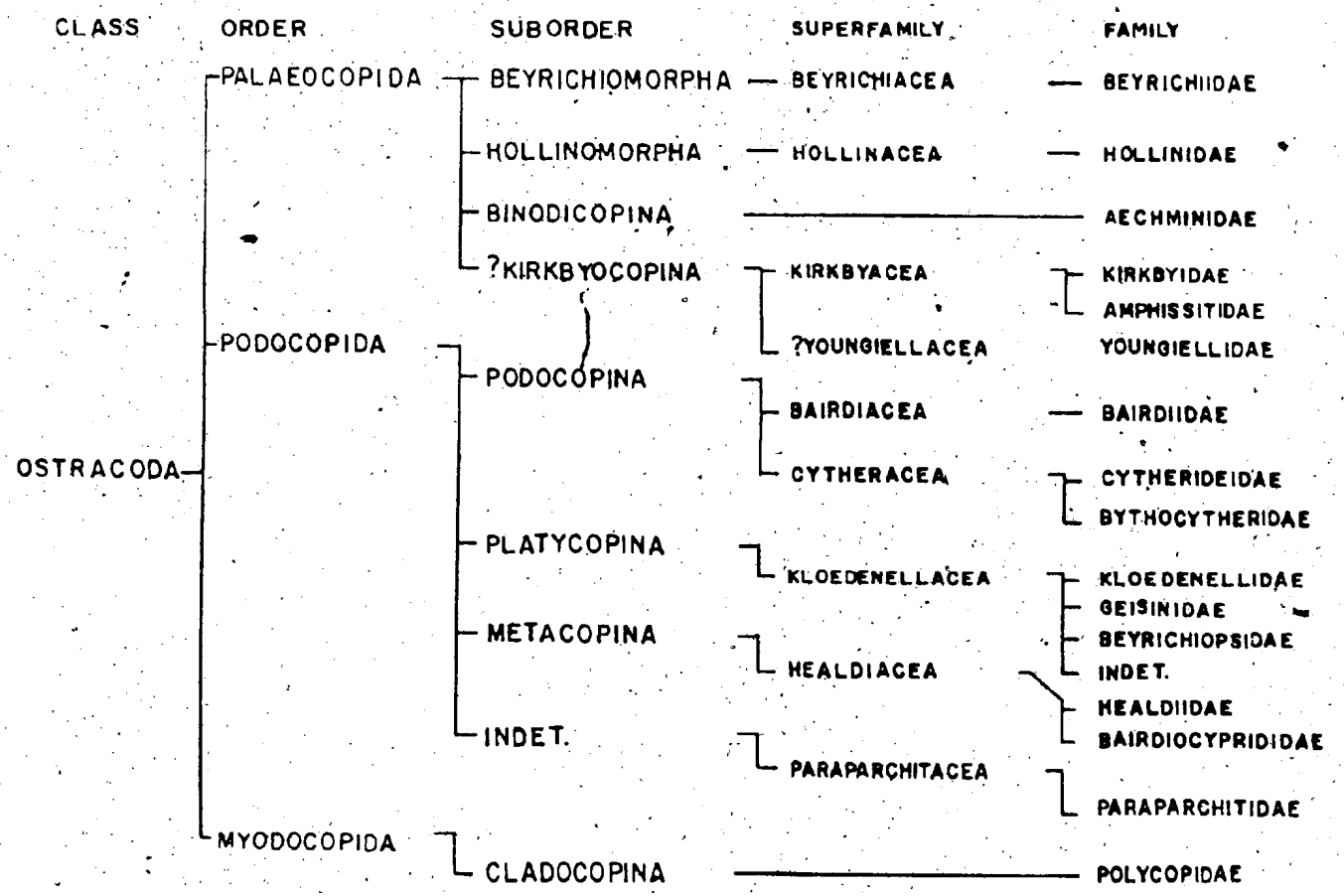
Limb morphology, jaw apparatus and nature of the cephalic region in crustaceans is markedly unlike that of any other arthropod group, therefore they are ranked at a high level as a separate taxonomic entity. The classification used herein at the class and phylum level is based upon the work of Manton (1973, 1977). Only specimens from two classes within the phylum Crustacea Pennant 1777, (*sensu* Manton, 1973) are described in this study.

6.1.2 Ostracode taxonomy

The Treatise on Invertebrate Paleontology, Part Q, Arthropoda, (Moore, 1961) dealing with ostracodes, is in the process of being rewritten, however the basic classification of the Treatise is used in the present study but with some modifications (Text-fig. 6.1). These modifications reflect more recent research that focusses upon the relationships of groups within the order Palaeocopida Henningsmoen, 1953.

Ostracodes described in this thesis remaining within the Palaeocopida fall into three suborders : Beyrichiomorpha Henningsmoen, 1965 ; Hollinomorpha Henningsmoen, 1965 ; and Binodicopina Schallreuter, 1972. The superfamilies Kloedenellacea Ulrich and Bassler, 1908 ; Kirkbyacea Ulrich and Bassler, 1906 ;

Text-fig. 6.1 : Chart of suprageneric ostracode classification adopted for this study.


CLASS
ORDER
SUBORDER
SUPERFAMILY
FAMILY
OSTRACODA
PALAEOCOPIDA
BEYRICHIOMORPHA
BEYRICHIACEA
BEYRICHIIDAE
HOLLINOMORPHA
HOLLINACEA
HOLLINIDAE
BINODICOPINA
AECHMINIDAE
?KIRKBYOCOPINA
KIRKBYACEA
KIRKBYIDAE
AMPHISSITIDAE
?YOUNGIELLACEA
YOUNGIELLIDAE
PODOCOPIDA
PODOCOPINA
BAIRDIACEA
BAIRDIIDAE
CYTHERACEA
CYTHERIDEIDAE
BYTHOCYTHERIDAE
PLATYCOPINA
KLOEDENELLACEA
KLOEDENELLIDAE
GEISINIDAE
METACOPINA
BEYRICHIOPSIDAE
HEALDIACEA
INDET.
HEALDIIDAE
BAIRDIOCYPRIDIDAE
INDET.
PARAPARCHITACEA
PARAPARCHITIDAE
MYODOCOPIDA
CLADOCOPINA
POLYCOPIDAE

and Paraparchitacea Scott, 1959 ; traditionally considered as palaeocopes are reassigned or questioned.

The Kloedenellacea are placed in the suborder Platycopina Sars, 1866, due to the presence of a narrow inner lamella, typically right over left overlap, poorly defined sexual dimorphism and kloedenellid hinge. This classification was used by Adamczak (1966, 1968), Bandel and Becker (1975) and Becker and Sanchez de Posada (1977). In this study the subordinal rank of Platycopina is retained following Moore (1961), Kesling and Chilman (1978) and Pokorny (1978). This is contrary to the work of Grundel (1967) and Bandel and Becker (1975) but retains the uniformity of the Treatise classification of the Podocopida (Text-fig. 6.1) until further agreement is reached concerning the status of all suborders within the Podocopida.

Grundel (1969), erected the suborder Kirkbyocopina within the order Beyrichiida Pokorny, 1953 (= Beyrichiocopina Scott, 1961) for all palaeocopes lacking velar structures and histial or cruminal dimorphism. This included the superfamilies Drepanellacea Ulrich and Bassler, 1923, and Kirkbyacea Ulrich and Bassler, 1906. Bandel and Becker (1975) placed the Kirkbyocopina within the order Platycopida; Bandel and Sanchez de Posada (1977) and Becker (1981), however, re-established it within the Palaeocopida. In the scheme suggested by Becker and Sanchez de Posada (1977), the Kirkbyocopina is restricted to the Kirkbyacea and the suborder Binodicopina Schallreuter, 1972, is used to accommodate the Drepanellacea. Pokorny (1978) places the

Kirkbyocopina, consisting of only the Kirkbyacea within an undefined order. In this study it is questionably retained within the Palaeocopida to underline the fact that at this time the true affinities of this group are uncertain, although most authors still retain the Kirkbyocopina within the Palaeocopida.

It is clear that members of the Paraparchitacea possess a wide inner lamella. It was therefore placed within the order Podocopida Muller, 1894, suborder indet. (Sohn, 1971). The simple hinge structure, the muscle scar consisting of many secondary scars in a quite compacted field as well as the wide inner lamella, make it difficult to assign the Paraparchitacea at a subordinal level. The Platycopina typically possess a biserial aggregate of scars, and the inner lamella is narrow or absent. The Metacopina may possess a simple hinge, but the aggregate muscle scar field is quite unlike those described for the Paraparchitacea, and the inner lamella is typically absent. The Podocopina typically possess a wide inner lamella, but the hinge is often differentiated into three or more elements and the muscle scars are dissimilar to those of the Paraparchitacea. For these reasons it is considered unlikely that the Paraparchitacea belong in any of the presently defined suborders of the Podocopida, and is therefore classified within a suborder indet.

6.1.3 Malacostracan taxonomy

Only two species of Malacostraca are described in this work and both of them fall within the same suborder. It was decided to use the suprasubordinal classification of Schram (1979)

as opposed to that of Brooks (1962, 1969), since it stresses the similarities between pygocephalomorphs and other peracarids. The classification is based upon more complete material than described herein and is therefore not discussed in detail. The classification of Schram (1981b) utilising the category "cohort" was not adopted herein, in order to maintain uniformity of taxonomic levels used throughout the systematic descriptions.

6.2 Systematic descriptions

Phylum CRUSTACEA Pennant, 1777

(*sensu* Manton, 1973)

Class OSTRACODA Latrielle, 1806

(= Ostrachoda Latrielle, 1802, Ostrapoda Straus, 1821).

Order PALAEOCOPIDA Henningsmoen, 1953

nom. transl. et correct. Scott and Moore, 1961, ex Paleocopa Henningsmoen, 1953

Diagnosis : Valves equal to subequal. Dorsal margin long and straight, with simple ridge and groove hinge. Strong outer calcareous layer of shell, inner lamella absent. Carapace nonlobate to quadrilobate, typically ornamented with nodes, spines, ribs or carinae and also with reticulate, punctuate, granulose or smooth surface. Sexual dimorphism domiciliar or extradomiciliar, some groups may be non-dimorphic. (Adapted from Moore, 1961; Becker and Sanchez de Posada, 1977).

Suborder BEYRICHIOMORPHA Henningsmoen, 1965

Diagnosis : Palaeocopida with domiciliar dimorphism.

Superfamily BEYRICHIACEA Matthew, 1886

nom. transl. Ulrich and Bassler, 1923 ex Beyrichiidae Matthew 1886.

Diagnosis : Straight hinged ostracode with subequal ends or forward swing, mostly with well developed lobes and sulci and showing a tendency to develop carinae, velar and marginal structures. Dimorphism well defined.

Family BEYRICHIIDAE Matthew, 1886

nom. transl. et correct. Ulrich, 1894 ex Beyrichinae Matthew, 1884.

Diagnosis : Straight hinged, non-sulcate to trisulcate, marginal ridge or frill commonly present, dimorphism well marked, females invariably with cruminal pouch.

Type-genus : *Beyrichia* M'Coy 1846

Stratigraphic range : Middle Ordovician to lower Carboniferous.

Genus *Copelandella* Bless and Jordan, 1971.

Diagnosis : see Bless and Jordan, 1971a p. 186.

Type-species : *Beyrichia Nova-Scotica* Jones and Kirkby, 1884.

Stratigraphic range : Lower Carboniferous

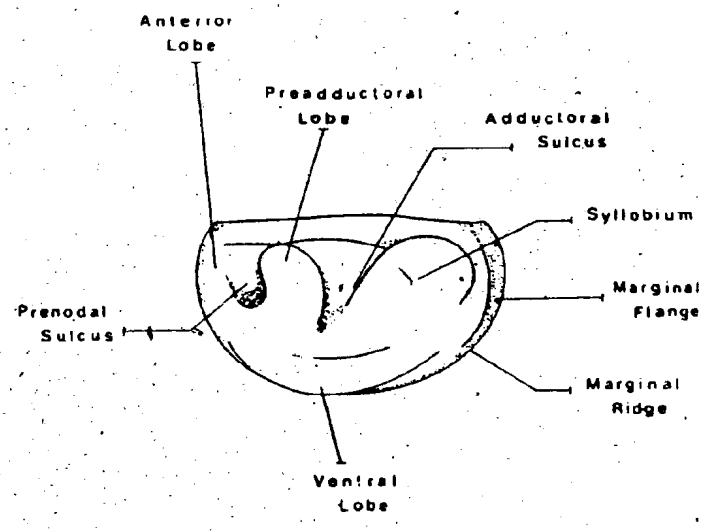
"Copelandella" sp.

Pl. 1, figs. 1 - 4

Text-fig. 6.2

Material : 8 Poorly preserved carapaces and 2 valves; all juveniles.

Description : Carapace smooth, lobate, sulcate, preplete, and sub-oval in outline. Valves sub-equal in size, right valve being only slightly larger than left. In juveniles of this collection all lobes are confluent, anterior, preadductoral lobes and syllobium poorly defined and continuous with ventral lobe. Adductoral sulcus broad and sweeps forward, prenodal sulcus weak and anterior lobe suppressed and flattened. Vestiges of marginal, velar ridge, and narrow marginal surface. Hinge straight and slightly shorter than maximum length, dorsal ridge extends above maximum dorsal extent of lobes. Cardinal angles slightly obtuse; posterior angle closest to 90°. Cardinal angles wider in cross section than hinge. Posterodorsal process not observed.



Text-fig. 6.2 Morphology of *"Copelandella"* sp.

Localities : SC. Nodo. 4, Wo. 2, Wo. 5.

Dimensions : All dimensions given hereafter are in microns unless otherwise stated.

L	H	W	
425	250	225	Pl. 1 figs. 1 - 3
375	225	225	Pl. 1 fig. 4

Occurrence: Southwestern Newfoundland

Remarks : *Copelandella novascotica* (Jones and Kirkby, 1884), originally described from the Horton district of Nova Scotia, has been suggested to have had non-marine affinities (Bell, 1960) but Bless and Jordan (1971a) prefer to consider a nearshore marine due to the co-occurrence of paraparchitaceans. The *Nodosinella* Band is suggested as being a sheltered nearshore environment subjected to varying salinities (Knight, 1983).

Suborder HOLLINOMORPHA Henningsmoen, 1965

Diagnosis : Palaeocopida with extradomiciliar dimorphism.

Superfamily HOLLINACEA Swartz, 1936

nom. transl. Kesling (in Moore, 1961) ex Hollinidae Swartz, 1936.

Diagnosis : Hollinomorphan ostracodes with anterior or posterior situated dolonate or locular velar structures. Lobation prominent.

Family HOLLINIDAE Swartz, 1936

sensu Bless and Jordan, 1971a.

Diagnosis : See Bless and Jordan, 1971a p. 877.

Type-genus : *Hollina* Ulrich and Bassler, 1908.

Stratigraphic range : (?lower Devonian) middle Devonian to upper Carboniferous.

Genus *Gortanella* Ruggieri, 1966

Diagnosis : See Ruggieri, 1966 p. 2.

Type-species : *Gortanella regina* Ruggieri, 1966.

Stratigraphic range : (herein amended) lower to upper Carboniferous.

Gortanella sp.

Pl. 1 figs. 5 - 9

Text-fig. 6.3

Material : 8 silicified more or less flattened carapaces.

Description : A hollinid ostracode with preplete quadrilobate domicilium and semicircular outline with anterior ventral swing. Dorsal margin straight with slightly obtuse cardinal angles. Posterior border more steeply rounded than anterior, resulting in forward swing. Maximum length inclined from posterior cardinal angle to point of maximum curvature of anterior border. Hinge line about 5/6 the maximum length. Maximum width poorly defined as being at site of L3.

L1 and L4 seem to be confluent via ventral lobe, L2 and L3 being more discrete. L2 smaller and lower on the domicilium than L3 which almost reaches dorsal border. S2 deepest and widest at mid-height. Lobation stronger in later instars.

The ventral border marked by a pair of adventral spurs, but no indication of true velar frill. Adventral spurs

always broken and minor marginal spines might have been present. Posterior cardinal spine always present. (Text-fig. 6.3)

Valve overlap not discernable.

Dimensions :

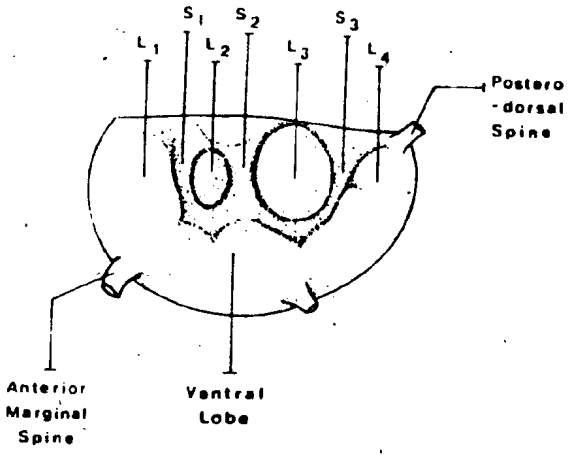
L	H		
1150	650	Pl. 1	fig. 7.
1000	575	Pl. 1	figs. 5,6.
850	475	Pl. 1	fig. 8.
675	375	Pl. 1	fig. 9.

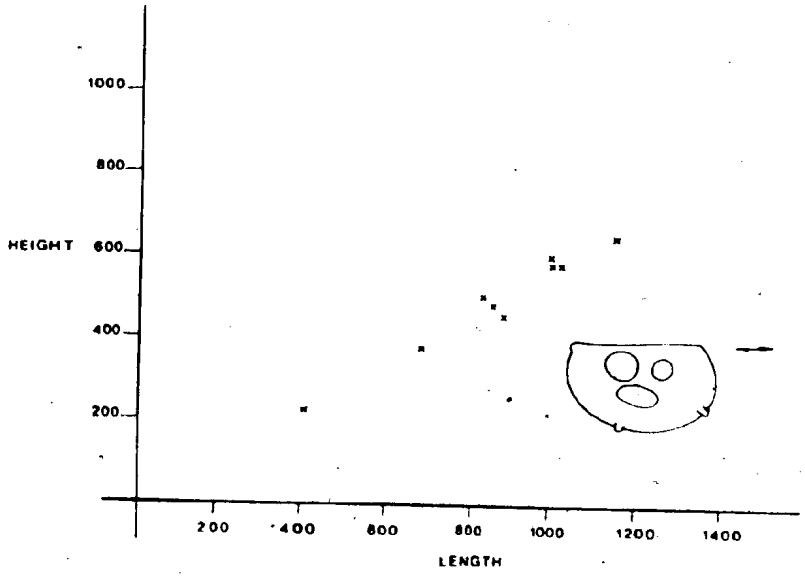
Locality : Crabb 2 - 5

NS. 3

Occurrence: Southwestern Newfoundland, Hants County Nova Scotia.

Remarks : The size groupings of the scattergram (Text-fig. 6.3) indicate that 5 instars are present in the collections. From the size and form of the carapaces it is concluded that they are juveniles. This presents the problem of differentiating the form of *Gortanella* sp. from *Hollinella (Keslingella) radiata* (Jones and Kirkby, 1886). According to the definition of *Gortanella* Ruggieri, 1966, the juveniles lack a velar frill, however, Bless and Jordan (1971b) suggest that this is a matter of preservation and preparation of specimens. Ruggieri (1966) further suggests that *Hollinella longispina* (Jones and Kirkby, 1886) might be better placed in the genus *Gortanella*, a fact reiterated by Sohn (1977). Bless and Jordan (1972), however, place *H. longispina* and its synonyms in synonymy with *H. (K.) radiata* and suggest that they represent juveniles of this form. The ontogenetic development of *H. (K.) radiata* is inferred by Bless and Jordan (1971b, 1972) to involve the loss of the anterior adventral spur as the velar frill develops. Ruggieri (1966)





Text-fig. 6.3 : Morphology and growth sequence of *Gortanella* sp. from Assemblage VI.

Note : All measurements on plots hereafter in microns unless stated.

suggests that as the instars develop, a frill is produced involving the spurs and indicates that in *Gortanella regina* Ruggieri, 1966, the spurs are preserved throughout ontogeny, which is more consistent with a continuous development of form. If, as Bless and Jordan (1971b) suggest, the absence of a juvenile frill in the genus *Gortanella* is a function of preservation and/or preparation, then at present there is no way of telling these two forms apart in this collection until adult specimens are found.

It is beyond the scope of this study to examine both *H.* (*K.*) *radiata* and *Gortanella*, however, it is suggested that the following forms be investigated in the light of the possibility that they could all be placed in the genus *Gortanella* Ruggieri, 1966, as a reassigned form *G. longispina* (Jones and Kirkby, 1886c):-

Beyrichia longispina Jones and Kirkby, 1886c, pp. 257, 258, Pl. 8 fig. 3.

Hollina longispina (Jones and Kirkby, 1886c) Ulrich and Bassler, 1908, p. 315.

Hollina longispina (Jones and Kirkby, 1886c) Latham, 1933, p. 361, fig. 9

Hollinella longispina (Jones and Kirkby, 1886c) Cooper, 1941, pp. 45, 46, Pl. 9 fig. 48, 49.

Hollinella longispina (Jones and Kirkby, 1886c) Posner, 1951, pp. 48, 49, Pl. 8 figs. 3,4.

Hollinella ex. gr. longispina Bushmina, 1968, p. 40 Pl. 5 fig. 11.

Hollina stepanovi Batalina, 1926, pp. 1328, 1335, Pl. 22 figs. 13-16, Pl. 23 figs. 23,24.

Hollinella swania Brayer, 1952, p. 169, Pl. 28 figs. 13a,b.

Bless and Jordan (1972 p. 17) suggest that there was a migration of the form *Hollinella* (*Keslingella*) from Russia via western Europe to the North American Mid-Continent during the upper Devonian and lower Carboniferous, but if the specimens of this collection belong to the genus *Gortanella* Ruggieri 1966, then little can be said of their geographical distribution since the genus has only been described from the upper Carboniferous of the Carnic Alps (Ruggieri, 1966) and the Chesterian of Arkansas (Sohn, 1977).

Suborder BINODICOPINA Schallreuter, 1972

Diagnosis : non dimorphic Palaeocopida.

Family AECHMINIDAE Boucek, 1936

nom. transl. Swartz, 1936 ex Aechmininae Boucek, 1936.

Genus *Aechmina* Jones and Holl, 1869

Diagnosis : See Jones and Holl, 1869, p. 217.

Type-species : *Aechmina cuspidata* Jones and Holl, 1869.

Stratigraphic range : Middle Ordovician to middle Mississippian.

Aechmina sp.?

Pl. 3 figs. , 1a.

Material : Single internal cast of left valve.

Description : Obliquely semicircular outline, straight hinge. Cardinal angles abtuse, posterior being moreso than anterior. Anterior border is more broadly rounded than posterior, which

sweeps forward in gentle curve. Ventral margin interrupted by small sub-central overhang, which is continuous with posterior border. Maximum height just anterior of midlength; maximum length below hinge, inclined antero-ventrally and about twice height. Large spine present in dorsolateral area slightly to rear of centre. Spine oblique to valve and protrudes dorsally. A small node-like swelling in front of spine is confluent with spine base. Spine base elliptical, and dorsal side of base almost continuous with dorsal margin. Since specimen is internal cast, original spine was hollow, probably longer than preserved length. Lack of shell material prevents description of external marginal detail.

Dimensions :

L	H	
975	500	Pl. 3 figs. 1, 1a.

Locality : Ag. 3

Occurrence: Port au Port Peninsula, western Newfoundland.

Remarks : The upper range of *Aechmina* is often given as middle Mississippian (Levinson in Moore, 1961) and records of the genus in the Carboniferous are rare. Two such descriptions are *Aechmina longicornis* from Kinderhookian (Ulrich and Bassler, 1923) and *Aechmina carbonifera* from the Carboniferous Limestone of England, (Smith, 1911). An unsubstantiated record of *Aechmina* in the Pennsylvanian is that of Knight (1928), but the description and figures of the specimen do not allow the true affinities to be stated.

Suborder KIRKBYOCOPINA Grundel, 1969

Diagnosis : Palaeocopida? often possesing kirkbyan pit, adventral structures, carinae and frequently a reticulated ornament. Non-dimorphic.

Superfamily KIRKBYACEA Ulrich and Bassler, 1906

nom. transl. Sohn (in Moore, 1961) ex Kirkbyidae Ulrich and Bassler, 1906.

Diagnosis : See Sohn in Moore, 1961, p. 163.

Family KIRKBYIDAE Ulrich and Bassler, 1906

Diagnosis : See Sohn in Moore, 1961, p. 164.

Genus *Kirkbya* Jones, 1859

Diagnosis : See Sohn in Moore, 1961, p. 164.

Type-species : *Dithryocaris permiana* Jones, 1850.

Stratigraphic range : Lower Mississippian to middle Permian.

Kirkbya n. sp. A.

Pl. 3 figs. 2 - 6; Pl. 4 figs. 1 - 6

Text-fig. 6.4

Material : 192 carapaces and valves.

Diagnosis : Typical *Kirkbya* morphology but possessing anterior cardinal spines and tubercle in place of true kirkbyan pit.

Description : Elongate, semicircular, amplete carapace, straight hinge. Cardinal angles almost 90°. Maximum length equal to, or just below, hinge line; maximum width central, carapace tends to be

tumid. Posterior shoulder poorly defined and hinge impressed slightly into dorsal margin. Two marginal carinae and narrow unornamented marginal surface present. All carinae converge at cardinal angles. Inner carina strong, sub-parallel to valve margins and situated higher on lateral surface than outer carina. Area between inner and outer carinae coarsely reticulate, but reticulation is not as well defined as on rest of the lateral surface. Reticulation on lateral surface is finer, though still coarse, and shows no consistent pattern. Inner carina of each valve terminates at anterior cardinal angle in short stout spine angled upward and away from hinge line. No spines observed at posterior cardinal angle. Kirkbyan pit located below mid-height in a position just posterior of mid-length; Granular knob, where best developed, but never seen as pit, though may occur as non-granular, flat tubercle surrounded by 7 or 8 reticulations. Long axis of knob parallels hinge line. Hinge, where seen, of simple ridge and groove type, lacks terminal elements. Left valve is very slightly larger than right and overhangs ventral margin to small extent, in end view. No dimorphism.

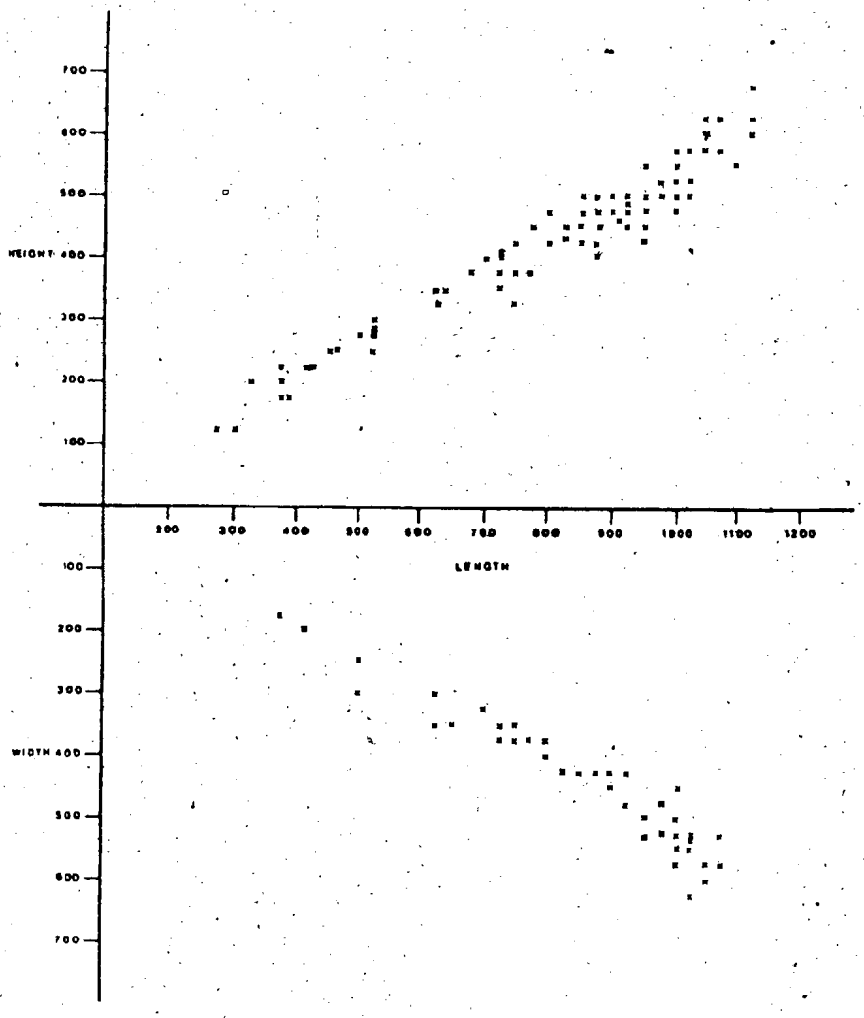
Dimensions :

L	H	W		
1050	575	-	Pl. 4	figs. 5, 6
975	525	-	Pl. 4	figs. 3, 4
950	500	500	Pl. 3	figs. 2 - 6
800	475	400	Pl. 4	figs. 1, 1a, 2

Locality : NS. 3

Occurrence: Hants County, Nova Scotia.

Remarks : The scattergram (Text-fig. 6.4) indicates that instar definition is poor and that there is a spread of values both



Text-fig. 6.4 : Growth sequence of *Kirkbua* n. sp. A. from Assemblage I

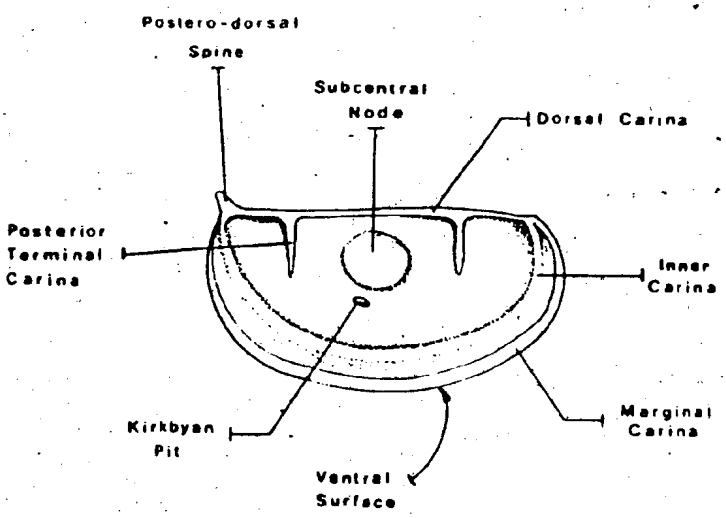
vertically and horizontally, (see section 4.10.3). This feature has been noted in other members of the superfamily described herein.

Sohn (1954, p. 8) discusses the occurrence of knobs in place of true kirkbyan pits and states "..... that the knobs replacing pits in some specimens are adventitous and not morphological structures." Having not examined *Kirkbya laciniata* Knight, 1928, I cannot say whether the knob described as occurring in this species (Knight, 1928, p. 255) is a function of preservation or not. However, in the specimens of this collection, wherever a "kirkbyan pit" can be seen it occurs as a tubercle, suggesting that it is not an adventitous feature.

In outline this species most closely resembles *K. symmetrica* Croneis and Thurmann, 1939. Since not all specimens posses spines, it is feasible that their non-occurrence is not diagnostic of other material. However the lack of ornamentation on the marginal surface and most importantly the "kirkbyan" tubercle are distinguishing features of this species.

Family AMPHISSITIDAE Knight, 1928

Diagnosis : Straight backed, subquadrate ostracodes, with often prominent central node sometimes flanked by anterodorsal and posterodorsal carinae or nodes. "Kirkbyan pit" usually occurs within or near subcentral node, if present. One or two marginal ridges flank free margin. No dimorphism has been observed. (Text-fig. 6.5) (Adapted from Sohn, 1961; and Grundel, 1965).



Text-fig. 6.5 : Typical amphissitid morphology.

Genus *Amphissites* Girty, 1910

Diagnosis : See Sohn, 1961, p. 115

Type-species : *Amphissites rugosus* Girty, 1910

Amphissites sp. aff. *A. centronotus* (Ulrich and Bassler, 1906).

Pl. 2 figs. 6 - 8

Text-fig. 6.6

Material : 6 carapaces and 3 valves well preserved.

120 assorted poorly preserved carapaces and valves.

Diagnosis : Typical *Amphissites* (Text-fig. 6.5) but with vestigial terminal carinae, and uniformly medium reticulation over whole carapace surface except on ventral surface which is unornamented.

Description : Carapace elongate ovate, with straight dorsum. Maximum length just above mid-height. Maximum height at mid-length. Hinge is slightly shorter than maximum length, also depressed into the dorsal margin. Cardinal angles obtuse, anterior angle being slightly larger than posterior. Dorsal shield elliptical in outline broadest posterially. Both inner carina and marginal flange are smooth and parallel convex ventral margins. Ventral area unornamented and narrows dorsally. Five rows of reticulations between the marginal flange and the inner carina. Faint posterior terminal carina present on largest specimen 4 reticulations in from inner carina, it is 4 reticulations long and continuous with dorsal shield. Reticulation of medium grade, uniform over valve surface and roughly concentric to valve margins. "Kirkbyan pit" obscured by ornamentation. Large dorso-lateral node situated just anteriorly of mid-line, about 1/3 of length of valve, quite distinct.

Dimensions :

L	H	W		
925	525	(550)	Pl. 2	fig. 8
700	375	-	Pl. 2	fig. 7
650	340	400	Pl. 2	fig. 6

Locality : NS. 4, B.1, B.7.

Occurrence: Antigonish County, Nova Scotia, and Port au Port Peninsula, western Newfoundland.

Remarks : Text-fig. 6.6 indicates that instar definition is poor. This species differs from *Amphissites centronotus* by lack of well defined terminal carinae, and the uniform reticulation. Finer ornament surmounting the central boss is described by (Knight, 1928; Bradfield, 1935; Sohn, 1954; Glass, 1967; Anderson, 1970; Becker, 1978). The height/length ratio is also smaller than that of *A. centronotus*. There are also 5 rows of reticulations between the marginal flange and the inner carina as opposed to 3 or 4 as in most descriptions of *A. centronotus*.

Genus et species novae.

Pl. 2 figs. 1 - 5

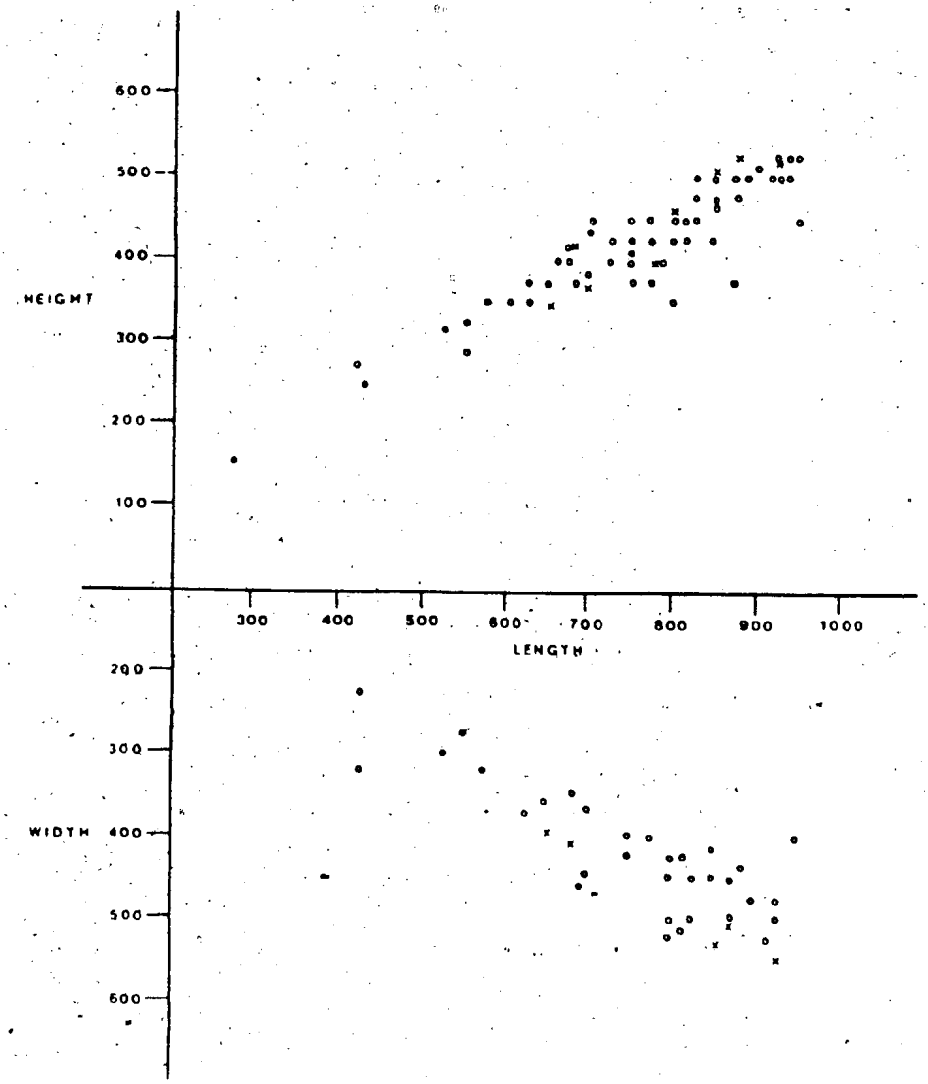
Text-fig. 6.7

Material : 39 assorted carpaces and steinkerns.

Diagnosis : Intermediate between *Amphissites* Girty, 1910 and *"Ectomedites"* Cooper, 1941. Form possesses single marginal carina, dorsal shield and prominent sub-central node. Terminal carinae and inner carinae absent.

Stratigraphic range : Middle Mississippian.

Description : Carapace subquadrate, with straight dorsal margin. Maximum length just above mid-height and maximum height at mid-length. Hinge slightly shorter than maximum length and incised into dorsal margin. Cardinal angles little over 90° and posterior cardinal angle supports pair of short indistinct spines angled upward (Pl.2 fig.1). Carapace anteriorly tapering wedge-shaped in dorsal aspect, dorsum marked by distinct shield formed by presence of dorsal carinae obliquely over-reaching dorso-lateral edge. Dorsal



Text-fig. 6.6 : Growth sequence of *Amphissites* sp. aff. *A. centronotus* from Sub-assemblage IIA(x) and Assemblage III(o)

shield and marginal flange continuous at cardinal angles. Marginal flange smooth, often poorly preserved, ventral surface is non-reticulate. Site of inner ridge marked by slight tumidity of sub-central ventral portion of lateral surface. Large node present in dorso-lateral position and overlies mid-line. Node about 1/3 of valve-length. Beneath node, angled toward posterior cardinal angle, is elongate "kirkbyan pit". Surface of valves are ornamented by roughly concentric, medium reticulation. No discernable valve overlap.

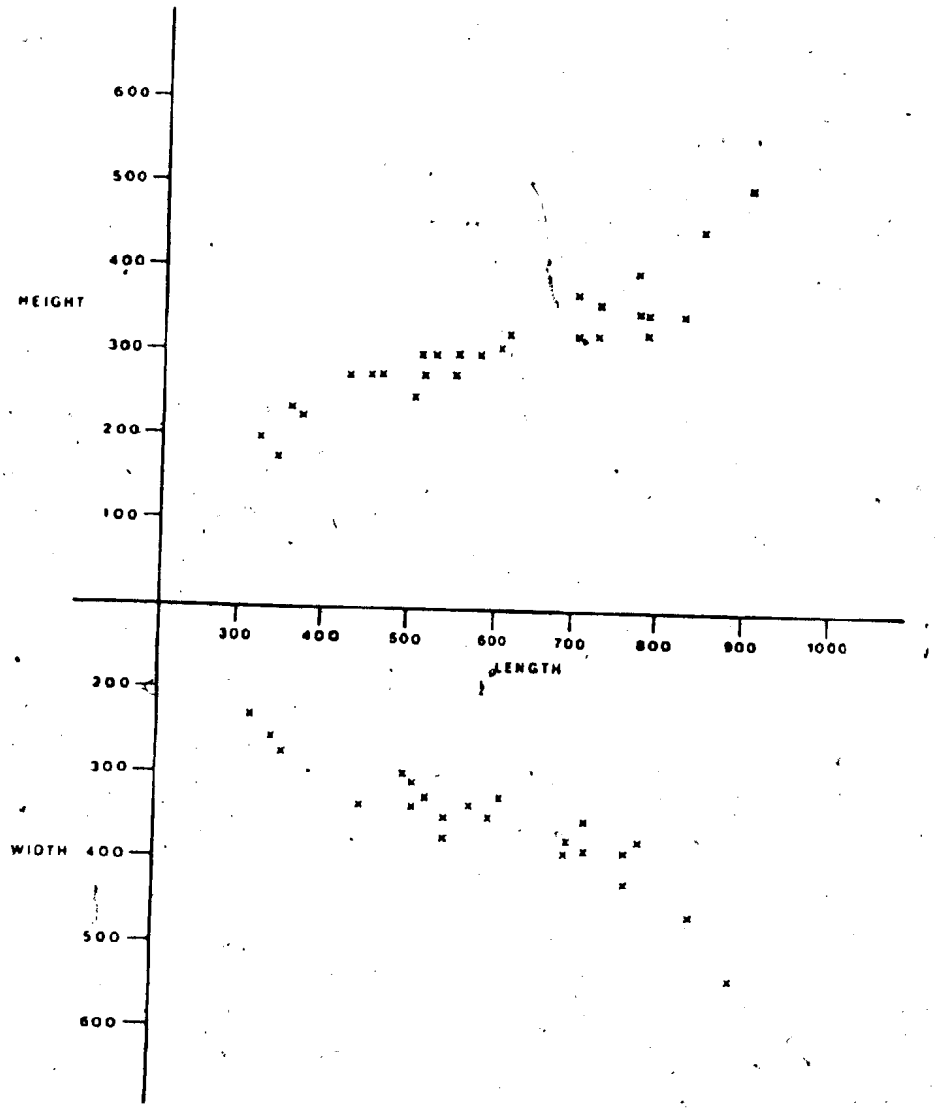
Dimensions : Figured specimens :	L	H	W		
Genotype	780	350	375	Pl. 2	figs. 3, 4
Paratype	775	400	420	Pl. 2	fig. 1
"	525	300	325	Pl. 2	fig. 2
"	510	280	330	Pl. 2	fig. 5, 5a

Locality : Ag. 2, Ag. 4, Ag. 5, Ag. Qu. 1

Occurrence: Port au Port Peninsula, western Newfoundland.

Remarks : A scattergram (Text-fig. 6.7) of this species indicates that the instars are poorly clustered, and, also, that there appears to be a variation between length and height, a feature that has been noted for other genera of the Kirkbyacea described in this study. The apparent asymmetry of the plot reflects the measurement of all specimens, including the steinkerns of the larger specimens, which are smaller than true carapace material.

Discussion : Sohn (1961), discussing the Amphissitidae Knight, 1928 gives a diagnosis and discussion of both *Amphissites* Girty, 1910 and "*Ectomedites*" Cooper, 1941, (Sohn, 1961, p. 115, 126). He provisionally retains the genus "*Ectomedites*" Cooper, 1941, and characterises it by the possession of two or more marginal carinae and the lack of terminal carinae. In the key (Sohn, 1961, p. 114),



Text-fig. 6.7 : Growth sequence of amphissitid gen. et sp. nov. from Sub-assemblage IIB.

"Ectomedites" is further distinguished by the absence of a dorsal keel, however, Sohn (1961, p. 126) states that the holotype of *"Ectomedites" primus* Cooper, 1941, has a very poorly preserved dorsal keel. In the Treatise (Sohn in Moore, 1961), *"Ectomedites"* Cooper, 1941 is put into questioned synonymy with *Amphissites* Girty, 1910. It would appear from the descriptions and figures of species attributed to *Amphissites* and *"Ectomedites"* by Morey (1955b, p. 477, Pl. 54 fig. 7), Croneis and Thurmann (1939, p. 311, pl. 8 fig. 10 - 12), Cooper (1941, p. 51, pl. 9 figs. 46, 47, 1945, p. 368; pl. 57 figs. 1 - 6, 21, 30, 1946, p. 103, pl. 15 figs. 37 - 39), Posner (1951, p. 64, pl. 12 figs 7, 8) and Zanina (1956, p. 233, pl. 5 figs. 8, 12, p. 231, pl. 5 figs. 9, 10), that a genus lacking a dorsal keel, with the characteristics ascribed to *"Ectomedites"* Cooper, 1941, does exist, but that the genotype is not typical of the genus. Sohn (1961) also reassigned the instars described by Cooper (1945, 1946) to another genus.

A third genus, *Neochilina* Matern, 1929, has a similar morphology to *"Ectomedites"* Cooper, 1941, in some respects. Originally assigned to the Eurychilinidae Ulrich and Bassler, 1923, by Matern (1929), it was removed therefrom by Swartz (1936) and Henningsmoen (1953). The Treatise (Howe in Moore, 1961, p. 413) classifies the genus as a *nomen dubium*. Blumenstengel (1965) described a new species of the genus and suggested an affinity with the Amphissitidae. Becker, (1981, pp. 33, 34) described another new species, left a further two species without names and assigned the genus as being possibly amphissitid.

Comparison of *"Ectomedites"* Cooper, 1941, and

Neochilina Matern, 1929, reveals that there are no terminal carinae in either genus and that a dorsal keel has never been described for *Neochilina* Matern, 1929. They differ, however, in two important aspects: the subcentral node is much more prominent in *Neochilina* Matern, 1929, than it is in "*Ectomedites*" Cooper, 1941, and there is only one marginal carina in *Neochilina* Matern, 1929.

The new genus described herein, is different from all of the above mentioned genera by the absence of terminal carinae; the supression of the inner carina and the presence of a dorsal keel. The node is intermediate in prominence between that of *Amphissites* or *Neochilina* and that of "*Ectomedites*".

It is interesting to note that steinkerns of the genus have a similar morphology to those described as *Albanella gouldi* Harris and Lalicker, 1932, and *Binodella binoda* Bradfield, 1935, which were placed in synonymy with *Amphissites centronotus* (Ulrich and Bassler), by Anderson (1970).

?Superfamily YOUNGIELLACEA Kellett, 1933

nom. transl. Sohn in Moore, 1961 ex Youngiellidae Kellett, 1933.

Diagnosis : See Sohn in Moore, 1961, p. 177.

Remarks : This superfamily is placed in the Kirkbyacea with considerable doubt. None of the assigned genera exhibit the "kirkbyacean pit", the lobation or the carination typical of the kirkbyaceans. The taxodont hinge that has been described by Jones and Kirkby (1886e) and Wilson (1933), is also atypical of the Kirkbyacea. It is not included in the suborder Kirkbyocopina Grundel, 1969.

Family YOUNGIELLIDAE Kellett, 1933

Diagnosis : Same as for superfamily.

Genus *Youngiella* Jones and Kirkby, 1895

Diagnosis : See Sohn in Moore, 1961, p. 177

Type-species : *Youngia rectidorsalis* Jones and Kirkby, 1886e.

Stratigraphic range : (?Upper Devonian), lower Mississippian to upper Pennsylvanian.

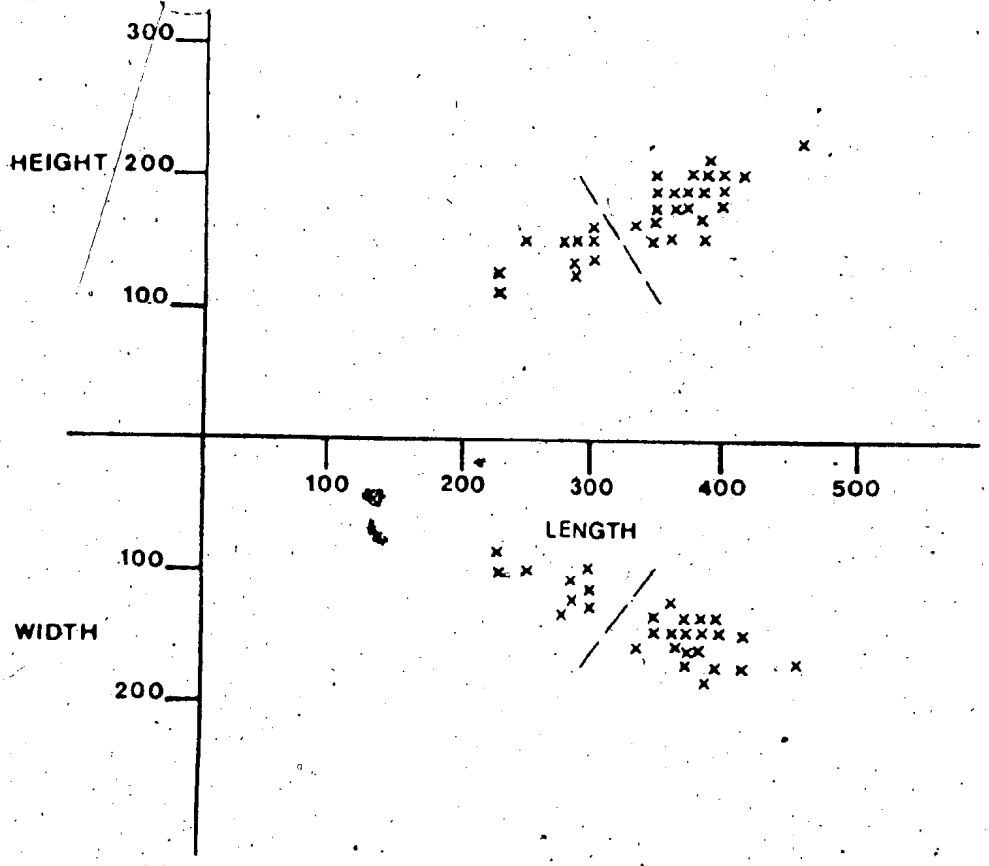
Youngiella sp.

Pl. 5 figs. 1 - 4

Text-fig. 6.8

Material : About 25 steinkerns.

Description : Small, smooth, elongate, subquadrate carapace with long, straight, centrally flattened dorsum. Cardinal angles about 95° with posterior angle less than anterior. Anterior margin more broadly rounded than posterior which curves slightly towards ventral margin. Ventral margin sub-parallel to dorsum and ventral swing results in maximum height being coincident with line drawn perpendicular to anterior cardinal angle. Ventral border concave centrally. Maximum length about twice height and parallels dorsum at about mid-height. Maximum width anterior of posterior cardinal angle and posterior of mid-length. Hinge straight, slightly depressed and about 3/4 maximum length. Left valve narrowly overlapped by right around free margins. In dorsal aspect carapace appears sub-lanceolate but posterior border is more truncated than anterior and also indented. No marginal rims.



Text-fig. 6.8 : Growth sequence of *Youngiella* sp. from Sub-assemblage IIB.

Dimensions :

L	H	W		
400	190	150	Pl. 5	figs. 3, 4
375	175	150	Pl. 5	figs. 1, 2

Locality : Ag. 2, Ag. 5, Ag. 6, Ag. Qu. 1,

B. 1, B. 2, B. 4, B. 5, B. 7.

Occurrence: Port au Port Peninsula, western Newfoundland.

Remarks : The present Treatise (Moore, 1961) definition of *Youngiella* Jones and Kirkby, 1895, separates it from *Moorites* Coryell and Billings, 1932, by the presence of marginal rims in the latter. Using this criterion it is clear that many species have been erroneously referred to *Youngiella* Jones and Kirkby, 1895. Species that are correctly referred to this genus indicate a stratigraphic range from the upper Viséan to the Westphalian; occurrences being later in the United States than in England and Russia. The following is a list of herein accepted species for *Youngiella* Jones and Kirkby, 1895, all other forms being incorrectly assigned to the genus:

1886e *Youngia rectidorsalis* Jones and Kirkby, p. 515, fig. 5 - 7.

1895 *Youngiella rectidorsalis* Jones and Kirkby, p. 456, pl. 21, figs. 5a - d.
Described from the Carboniferous limestone series of England.

1933 *Youngiella knighti* Wilson, p. 417, pl. 50, figs. 2a - c.
Described from the DesMoinian of Oklahoma.

1941 *Moorites elongatus* Cooper, p. 64, pl. 14, figs, 20, 21.
Described from the Chester of Illinois.

1946 *Youngiella knighti* Wilson, Cooper, p. 122, pl. 21, figs. 5, 6.
Described from the Desmoinian to Virgilian of Illinois.

1951 *Youngiella naviculata* Posner, pp. 71, 72, pl. 15, figs. 1 - 3.
Described from the Tulsky to Mikhailovsky horizons of the Russian Platform.

1964 *Youngiella elongata* (Jones and Kirkby) Gorak. pp. 190, 191, pl. 4, fig. 4.
Described from the $C_1^v f$ - $C_1^v g$ of the Donetz Basin.

1977 *Youngiella* sp. or spp. Sohn, p. 150, pl. 1, figs. 29 - 32, 39 - 46, pl. 2, figs, 1 - 3.
Described from the Chester-Morrowan of Oklahoma and Arkansas.

1981 *Youngiella* cf *calvatus* Lethiers, p. 41, pl. 4, fig. 40.
Described from the Frasnian to Famennian of Saskatchewan and Alberta.

Order PODOCOPIDA Muller, 1894

nom. correct Pokorny, 1953 pro Podocopa Muller, 1894

Suborder PODOCOPINA Sars, 1866

nom. correct Swain in Moore, 1961 ex Podocopa Sars, 1866

Superfamily BAIRDIACEA Sars, 1888

nom. transl. Sylvester Bradley, 1948 ex Bairdiidae Sars, 1888

Family BAIRDIIDAE Sars, 1888

Diagnosis : See Shaver and Hessland in Moore, 1961, p. 201.

Subfamily BAIRDIINAE Sars, 1888

Diagnosis : See Maddocks, 1969, pp. 14 - 16.

Genus *Bairdia* McCoy, 1844

Diagnosis : See Moore, 1961, pp. 202 - 203.

Type-species : *Bairdia curtis* McCoy, 1844

Stratigraphic range : Ordovician to Recent.

Bairdia brevis Jones and Kirkby, 1867

Pl. 5 figs. 5 - 10

Material : 25 carapaces and 3 valves.

Synonymy : 1867 *Bairdia brevis* Jones and Kirkby, p. 221.
1879 *Bairdia brevis* Jones and Kirkby, p. 575, Pl. 31, figs. 1 - 8.
1892 *Bairdia brevis* Jones and Kirkby, p. 305, Pl. 16, fig. 9.
1939 *Bairdia brevis* Jones and Kirkby, Kummerow, p. 45, Pl. 5, figs. 4a,b.
1951 *Bairdia brevis* var. *jonesi* Posner, p. 90, Pl. 20, figs. 4, 5, Pl. 21, figs. 5, 6.
1956 *Bairdia jonesi* var. *adiposa* Zanina, p. 248, Pl. 8, figs. 1a,b.
1967 *Bairdia (Bairdia) subbrevis* Gorak, p. 66, Pl. 17, figs. 6a,b.
1968 *Bairdia brevis* Jones and Kirkby, Bushmina, PP. 98, 99, Pl. 19, fig. 5.
1970 *Bairdia brevis* Jones and Kirkby, Bushmina, p. 36, Pl. 11, fig. 6.
1975 *Bairdia jonesi* Posner, Bushmina, P. 57, Pl. 12, fig. 4.
1981 *Rectobairdia? berniciana* Robinson, Bless et al., p. 149, Pl. 3, figs. 53, 54.
?1934 *Baidia deloi* Kellett, p. 126, Pl. 14, figs. 6a,b.
?1942 *Bairdia permiana* Hamilton, p. 715, Pl. 110, figs, 1a,b.

Description : Carapace subrhomboidal, height being about 3/4 length. Dorsal margin is strongly convex with steeper posterior slope than anterior. Demarcation of hinge-line and posterior slope less

prominent than demarcation of hinge-line and anterior slope. Hinge is short and inclined to posterior, which places maximum height at anterior cardinal angle. Anterior and posterior slopes are gently concave. Ventral border convex, but may be flattened centrally in some specimens, with slight angularity between ventral margin and anterior curve. Anterior extremity broadly rounded, to almost truncated, with supressed beak above mid-height. Posterior extremity more acuminate with pronounced beak below mid-height. Maximum length trends obliquely from one extremity to the other and parallels inclination of hinge-line. Maximum width at mid-length slightly behind maximum height, carapace tumid, having broad lenticular outline; width normally slightly greater than ½ length. Left valve overlaps right around free margins with pronounced ventral selvage in most specimens. Surface ornament generally lacking, some specimens show very faint punctuation.

Dimensions :

L	H	W		
900	550	500	Pl. 5	figs. 5 - 8
875	500	450	Pl. 5	fig. 10
725	500	400	Pl. 5	fig. 9

Locality : NS. 3.

Occurrence: Hants County, Nova Scotia, U.K. Ireland, Belgium, Germany, Russia, Mongolia, ?U.S.A.

Remarks : *Bairdia brevis* Jones and Kirkby, was first named in 1867, but since no description was given of the species at that time it became a *nomen nudum* as pointed out by Sohn (1960). Bassler and Kellett (1934, p. 167) credit the species to Jones and Kirkby, 1867, however the first description of the form was given in 1879. Jones

and Kirkby (1879, p. 575) stated that the form of the carapace is variable, and this has resulted in the species being shifted from genus to genus, and subdivided into sub-species. Robinson (1978, p. 152) placed the species in the *Cryptobairdia*, and Bless et al. (1981, p. 148) placed it in *Rectobairdia*. In Nova Scotian material there is no sign of a posterior spine, and although the anterior beak is supressed, it is not totally absent as in *Cryptobairdia berniciana* Robinson, 1978. Due to the arched dorsal margin and the presence of a weak anterior beak, the form is herein left within the genus *Bairdia*. Russian workers, including Posner (1951), Gorak (1967), and Bushmina (1968, 1970, 1975) have consistently attempted to subdivide the species, but all new descriptions are essentially within the framework established by Jones and Kirkby (1879). From the material of this collection it is impossible to separate minor variations into discrete groups; therefore to avoid nomenclatural duplication involving sub-species that are often indistinguishable from one another, the original description of Jones and Kirkby (1879), is taken to be correct, which allows for intraspecific variability (Cadot and Kaesler, 1973).

Bairdia sp. *L.* Sohn, 1960

Pl. 6 figs. 1 - 8

Text-figs. 6.9a,b

Material : About 200 assorted carapaces and valves.

Synonymy : 1879 *Bairdia plebeia* Reuss, Jones and Kirkby, P. 569, Pl. 28, figs. 9 - 14.

1941 *Bairdia attenuata* Girty, Cooper, p. 25, Pl. 1, figs. 33, 34.

1947 *Bairdia attenuata* Girty, Cooper, p. 84, Pl. 21, figs. 27, 28.

?1978 *Bairdia orientalis* Bushmina, Robinson, p. 152, Pl. 12, figs. 6a, b.

Description : Elongate carapace with gently curved dorsal margin in left valve which over-reaches straighter dorsal margin of right valve. Anterior slope less steep than posterior, both slightly concave. Angle between hinge-line of right valve and anterior and posterior slopes more pronounced than between corresponding parts of left valve, which is more uniform in outline. Ventral margin straight with slight selvage developed anterior of mid-length. Ventral margin curves broadly up into extremities. Posterior beak more acuminate than anterior and has definite angle with ventral margin. Posterior beak situated just below mid-height and anterior beak situated just above mid-height. Anterior beak more broadly rounded than posterior beak. Maximum length slightly below mid-height, and maximum height at mid-length. Maximum width median, carapace lanceolate in dorsal outline with tapered to almost pointed ends. Wide inner lamella with anterior and posterior vestibules present. Carapace smooth.

Dimensions :

L	H	W		
1275	625	460	Pl. 6	figs. 7, 8.
1275	600	430	Pl. 6	figs. 5, 6.
1100	480	400	Pl. 6	figs. 1 - 4.

Locality : Ag. 2, Ag. 4, Ag. 5, Ag. Qu. 1, Mi. 1, Wo. 4, NS. 3, NS. 4.

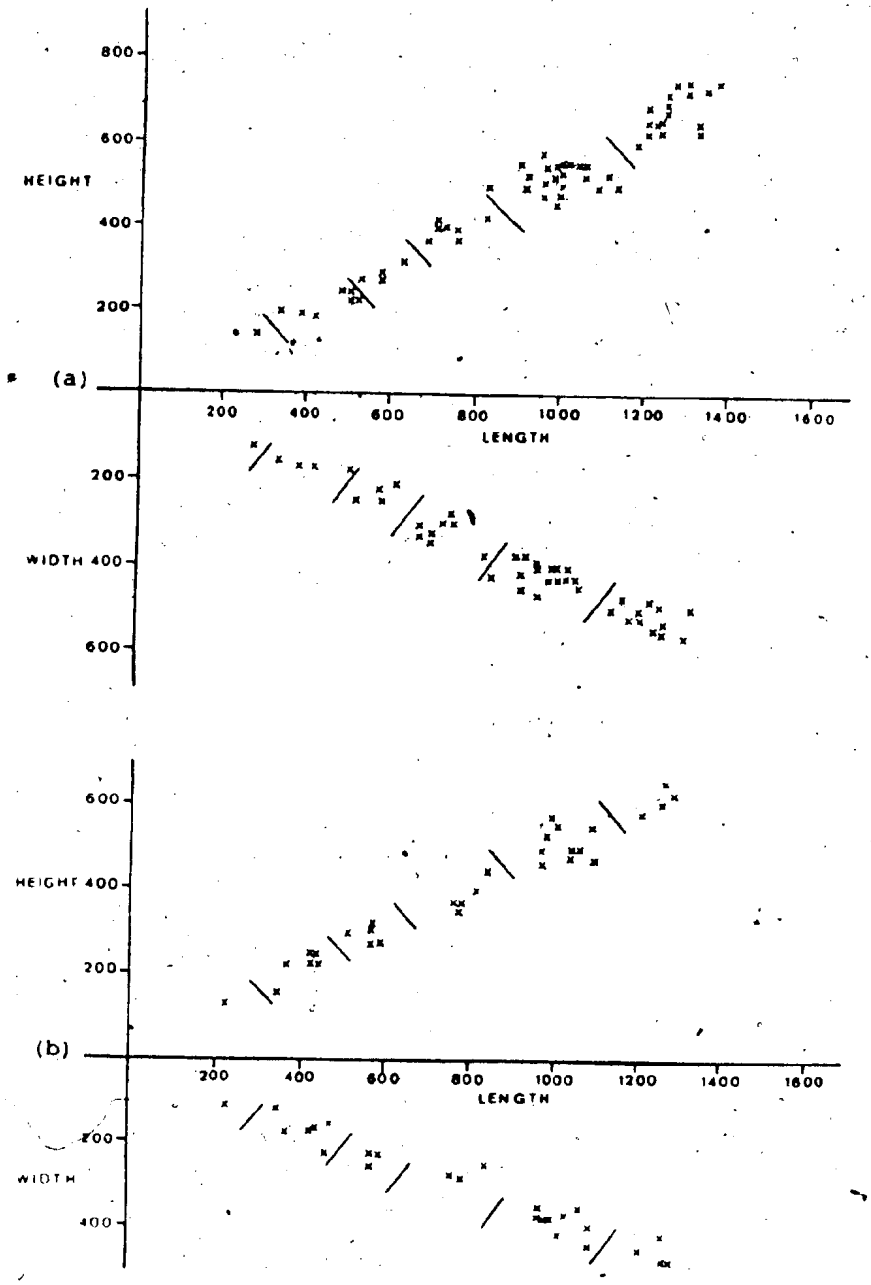
Occurrence : Southwestern Newfoundland; Hants and Antigonish Counties, Nova Scotia; U.K.; Illinois, U.S.A.

Remarks : This form is very similar to *Bairdia orientalis* Bushmina, 1975, however, *B. orientalis* shows a greater angularity of the dorsal margin and slope, together with a slightly longer hinge-line. It is possible that *B. orientalis* should be included in synonymy with *Bairdia* sp. *L.*. In the material from the Maritimes of Canada, it is frequently impossible to differentiate the forms having a straighter dorsal margin from those with a more rounded dorsal margin, because there appears to be a continuous variation of this character. Pl. 6 fig. 1 is clearly the same as *B. orientalis* Bushmina, Robinson (1978), however, Pl. 6 fig. 5 is more closely akin to *Bairdia plebia* Jones and Kirkby, 1879 *sensu* Sohn, 1960; and Pl. 6 fig. 7 appears to form a link between the two extremes.

It is interesting to note that specimens from Nova Scotia (Text-fig. 6.9a) appear to be consistently higher and wider in the later instars than those from Newfoundland (Text-fig. 6.9b). For discussion of this phenomenon see sections 4.3.1 and 4.10.3.

Genus *Bairdiacypris* Bradfield, 1935

Diagnosis : See Bradfield, 1935, p. 93.



Text-fig. 6.9 : Growth sequences of *Bairdia* sp. 1. from

a : Assemblage I.

b : Sub-assemblage IIB.

Type-species : *Bairdiacypris deloi* Bradfield, 1935.

Stratigraphic range : Devonian to Permian.

Bairdiacypris quartziana (Egorov in Polenova, 1953).
Pl. 6 figs. 9 - 14.

Material : 48 carapaces and 9 valves.

Synonymy : 1953 *Bairdia quartziana* Egorov in Polenova, pp. 52, 53, Pl. 9, figs. 1a,b.
1953 *Bairdia quartziana* Egorov, P. 22, Pl. 13, figs. 1 - 6, Pl. 14, figs. 1 - 4, 8.
1953 *Bairdia* cf. *B. quartziana* Egorov, p. 24, Pl. 14, figs. 5 - 7.
1968 *Bairdia (Bairdiacypris) conspicua* Gorak, pp. 76, 77, Pl. 29, fig. 3.
1974 *Bairdiacypris* cf. *B. quartziana* (Egorov), Becker et al., p. 13, list, Pl. 5, fig. 9.
1981 *Bairdiacypris quartziana* (Egorov), Lethiers, p. 87, Pl. 19, figs. 180, 181.

Description : Elongate subovate outline. Dorsal margin straight with poorly defined shallow anterior slope. Posterior slope meets hinge-line at distinct angle. Ventral surface parallel to hinge-line, with slight concavity at mid-length. Anterior end broadly rounded with truncated beak above mid-height. Posterior end more acuminate and situated below mid-height. Maximum height, due to ventral concavity, at anterior end of hinge-line, forward of mid-length. Maximum length just above mid-height and maximum width central. Carapace lanceolate in dorsal aspect with rounded ends. Left valve narrowly overlaps right along anterior and posterior slopes as well as mid-ventrum. Surface smooth.

Dimensions :

L	H	W		
1375	525	400	Pl. 6	figs. 9, 10
1350	550	450	Pl. 6	figs. 13, 14
1250	475	450	Pl. 6	figs. 11, 12

Locality : NS. 3.

Occurrence : Hants County, Nova Scotia; Donetz Basin and Volga Region, Russia.

Subfamily ACRATIINAE Grundel, 1962

Diagnosis : See Grundel, 1962, pp. 85, 86

Genus *Acratia* Delo, 1930

Diagnosis : Carapace elongate and acuminate especially in posterior end. Dorsal and ventral margins convex with or without upswept curve in anterior third of ventral margin. Overlap only present along ventral and antero-dorsal margin, sometimes along postero-dorsal margin. Hinge straight and slightly curved. Inner lamella developed. (Adapted from Delo, 1930 and Grundel, 1962).

Type-species : *Acratia typica* Delo, 1930.

Stratigraphic range : Middle Devonian to middle Triasic.

Acratia acuta (Jones and Kirkby, 1895)

PL. 8 figs. 1 - 7

Text-fig. 6.10

Material : About 600 carapaces, valves and steinkerns.

Synonymy : 1895 *Argilloecia (Bythocypris?) aequalis* var. *acuta* Jones and Kirkby, pp. 457, 458, Pl. 21, fig. 8

1974 *Acratia* sp. aff. *A. rostrata* Zanina, (species 23) Becker and Bless, Pl. 38, figs. 3a,b,c.

Description : Elongate carapace. Posterior acuminate, anterior more broadly rounded. Dorsal margin evenly convex, with steeper posterior slope than anterior. Suggestion of concavity in antero-dorsal slope. Convex ventral margin has shallow anterior concavity which curves abruptly upward into anterior margin, making a rounded angle with anterior margin. Posterior end sharply pointed and higher than anterior margin. Posterior extremity is short point due to steepness of postero-dorsal slope and shallow ventral margin. Greatest length below mid-height and maximum height just anterior of mid-length. Maximum width median with biconvex lensoid outline in dorsal aspect. Overlap of left valve over right is most conspicuous in ventral margin and antero-dorsal slope.

Dimensions :

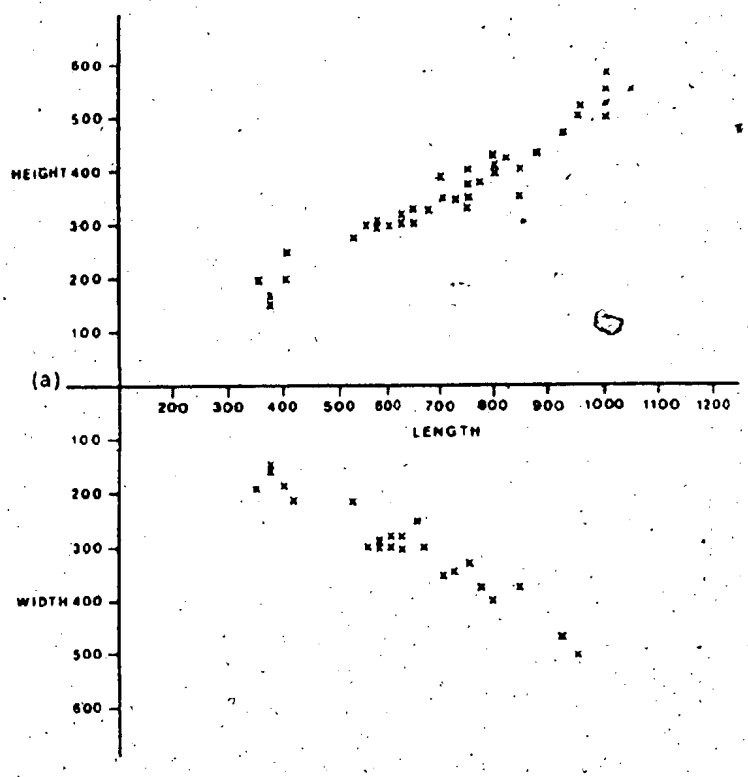
L	H	W		
800	325	310	Pl. 8	fig. 7
750	325	310	Pl. 8	figs. 1 - 4
625	275	250	Pl. 8	figs. 5, 6

Locality : B. 1, B. 2, B. 4, B. 5, B. 7, Ag. 2, Ag. 3, Ag. 4, Ag. 5, Ag. Bk. 3, Bk. 1 CR. Nodo. 4, SC. Nodo. 3, SC. Nodo. 4, Crabb. 2-5 NS. 3, NS. 4, NS. 5.

Occurrence: Southwestern Newfoundland; Hants and Antigonish Counties Nova Scotia; Belgium; U.K.

Remarks : There are several poorly clustered instars in Text-fig. 6.10 which indicate that variation exists between various environments in which it occurs. Instar definition is better in specimens from

Assemblage V (Text-fig. 6.10c), although specimens tend to be slightly smaller in all aspects than in Assemblages II and III (Text-fig. 6.10a,b). (See section 4.10.3). The form described herein appears identical to *Argilloecia (Bythocypris?) aequalis* var. *acuta*, however that form was not formally described by Jones and Kirkby (1895, p. 458). The form is not a variety of *Acutiangulata aequalis* (Jones and Kirkby), and, due to the antero-ventral concavity and the posterior acumination, should be placed within the genus *Acratia*. If specimens of Jones and Kirkby's original material can be found they should be designated as holotype and paratypes of *Acratia acuta* (Jones and Kirkby, 1895). *Acratia rostrata* Zanina, 1956, differs from *A. acuta* by virtue of the deeper concavity in the antero-ventral margin, broader dorsal arch and greater tumidity. Becker and Bless (1974, Pl. 38, figs. 1 - 5) describe a form of *Acratia* sp. aff. *A. rostrata* Zanina, of which their figs. 3a,b,c seem to be consistent with the description of *A. acuta* given herein. Their other illustrated specimens appear to be quite variable; some being much more quadrate in outline than the Maritime material (Becker and Bless, 1974, Pl. 38, figs. 1a,b,c,d), while others possess a much stronger ventral concavity (figs. 2b, 5). It is quite feasible that the illustrated specimens represent more than one single species. Becker et al. (1974, Pl. 13, figs. 3, 4), describe another form of *Acratia* sp. aff. *A. rostrata*, which differs from the Maritime specimens by its greater tumidity and more elongate extremities in dorsal aspect. This form may be conspecific with *Acratia* sp. aff. *A. rostrata sensu* Becker and Bless 1974, Pl. 38, figs. 4a,b.

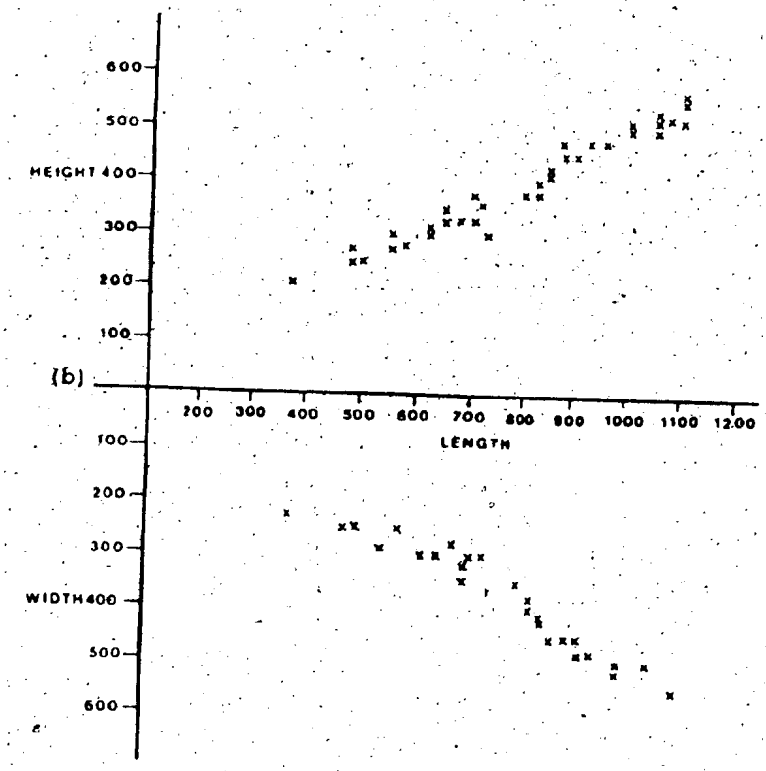


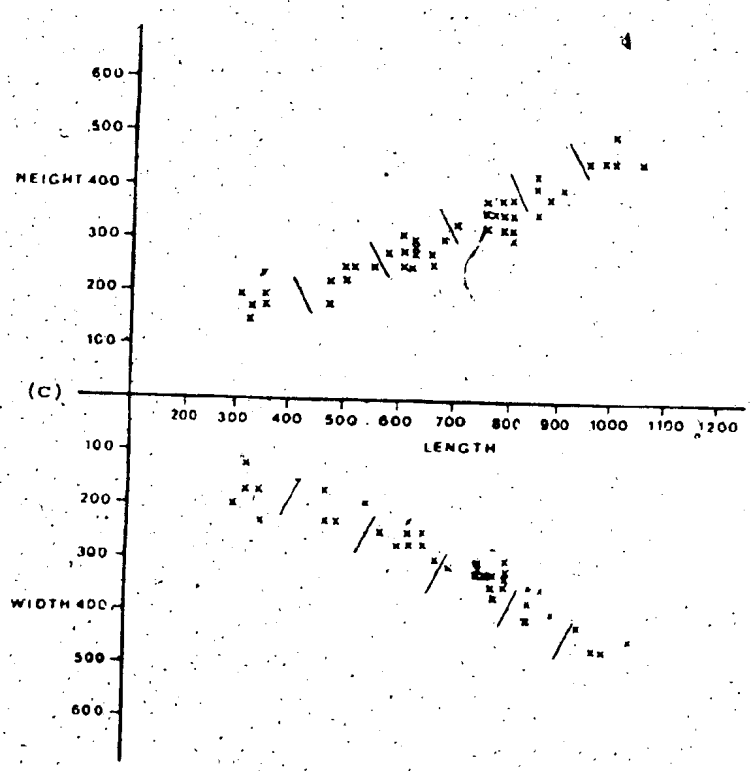
Text-fig. 6.10 : Growth sequences for *Acratia acuta* from

a : Assemblage II

b : Assemblage III

c : Assemblage V


HEIGHT
LENGTH
(b)


HEIGHT
LENGTH
(c)

The specimens described herein differ only slightly from *Acratia similaris* Morey, 1936, in that the figured specimen (Morey, 1936, Pl. 17, fig. 9) has a more pronounced angularity of the dorsal margin and posterior slope.

Genus *Acutiangulata* Bushmina, 1968

Diagnosis : See Bushmina, 1968, p. 91, and 1970, p. 53.

Herein translated from Bushmina, 1970, p. 53: *Acutiangulata* with roundish trapezoidal shell and slight pointed beak concentrated in right valve, on left valve posterior end narrowly rounded, front end is evenly rounded.

Type-species : *Carbonita acutiangulata* Posner in Tshigova, 1960.

Stratigraphic range : Carboniferous.

Remarks : No details of the inner lamella have been given for this genus.

Acutiangulata aequalis (Jones and Kirkby, 1886)

Pl. 7 figs. 1 - 4

Text-fig. 6.11

Material :About 200 valves and carapaces.

Synonymy : 1885 *Argilloecia aequalis* Jones and Kirkby, p. 540.

1886c *Argilloecia aequalis* Jones and Kirkby, PP. 263, 264, Pl. 9, figs. 6a,b.

1895 *Argilloecia aequalis* Jones and Kirkby, pp. 455, 456, 460.

1978 *Acutiangulata aequalis* (Jones and Kirkby), Robinson, p. 150, Pl. 11, figs. 1a,b.

Description : Rounded, elongate, subreniform carapace, with evenly arched dorsal margin, cardinal angles indistinct and hinge curved. Anterior slope steeper than posterior slope, extremities are rounded and low. Ventral margin has median concavity. Maximum length just above ventral margin, maximum height posterior. Maximum width median and dorsal aspect elongate ovate with rounded ends. Left over right overlap most noticeable in postero-dorsal slope and centro-ventral margin. Inner lamella present, with anterior and posterior vestibules. Beak in posterior corner of right valve suppressed.

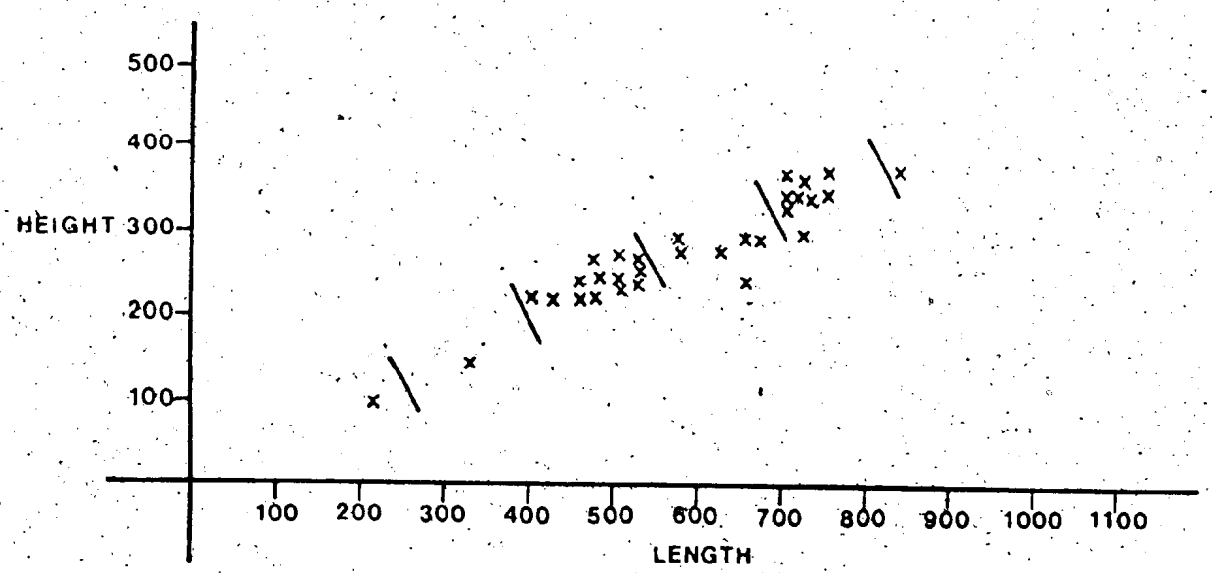
Dimensions :

L	H	W	
750	350	-	Pl. 7 fig. 4
725	350	325	Pl. 7 figs. 1 - 3

Locality : CR. Nodo. 4, SC. Nodo. 4, CC. 8, CC. 9
Wo. 5, Wo. 6, Wo. 10, NS. 3, NS. 4, NS. 5, NS. 6

Occurrence: Southwestern Newfoundland; Hants County, Nova Scotia.

Remarks : Text-fig. 6.11 indicates the presence of 6 possible instar groups and the uneven distribution of valves and lack of carapaces suggests post-mortem transport (see section 4.6). Robinson (1978, p. 150) states : " once considered to belong to *Carbonita*, this species may belong to the Russian genus *Acutiangulata* as redefined by Bushmina (1970)." In the present material there is no indication of the right posterior beaked corner which would be diagnostic of the genus. According to the original definition of the genus (Bushmina, 1968, p. 91) both the anterior and posterior ends of the right valve should be pointed; but this restriction was later relaxed to affect only the posterior corner (Bushmina, 1970).



Text-fig. 6.11 : Growth sequence for *Acutiangulata aequalis* from Assemblage V.

This species differs significantly from *Acutiangulata* n. sp. in the general outline and the lack of striations.

Acutiangulata n. sp. A.

Pl. 7 figs. 5 - 9

Text-fig. 6.12

Material : About 150 steinkerns, carapaces and crushed specimens.

Diagnosis : Tumid, trapezoidal species of *Acutiangulata* possessing fine stiate ornament.

Description : Elongate, tumid, trapezoidal carapace with arched dorsum, flat ventrum and left over right overlap. Cardinal angles indistinct, maximum height at dorso-posterior angle, maximum width ventral in plane of maximum height. Maximum length bisects posterior and anterior extremities at slight incline. Posterior end is more acuminate and lower than broadly rounded anterior margin. Dorso-posterior slope much steeper than antero-dorsal slope, which curves almost imperceptibly into anterior margin. Posterior corner ventral margin has very slight upturn. Right valve also pointed in posterior corner, whereas left valve rounded posteriorly. No anterior beak. Inner lamella widest at extremities narrow in mid-venter. (Details best seen on steinkern material). Indistinct circular muscle scar field as centrally flattened area on some specimens, details of field not known. Carapace covered with about twenty fine longitudinal striae which fade and converge at extremities of carapace, may bifurcate along their length.

Dimensions :

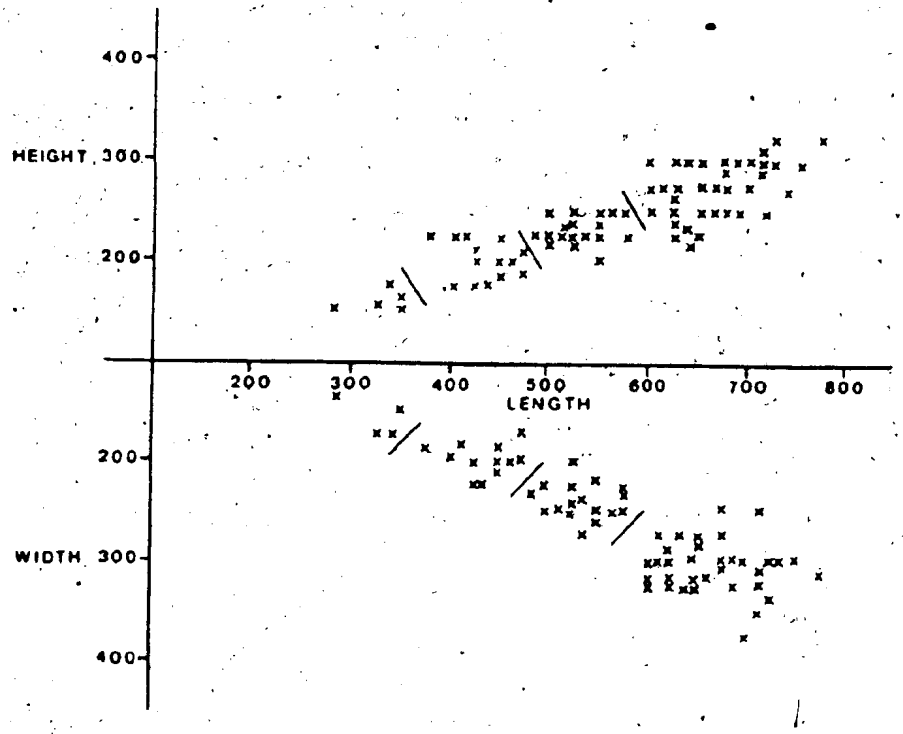
L	H	W	
675	250	250	Pl. 7 figs. 7, 8
650	280	260	Pl. 7 fig. 9
625	275	250	Pl. 7 figs. 5, 6

Locality : Ag. 2, Ag. 3, Ag. 4, Ag. 5, Ag. Qu. 1
B. 1, B. 2, B. 4, B. 5, B. 7

Occurrence: Port au Port Peninsula, western Newfoundland.

Remarks : The scattergram (Text-fig. 6.12) shows four poorly defined instar groupings and a fairly variable carapace morphology. With the exception of the lack of hinge over-reach, the reversal of overlap, the posterior point and the wide duplicature, this form is very similar to *Carbonita evelinae* Jones, 1870. Anderson (1970) states that the reversal of overlap is not uncommon in *Carbonita* Strand, 1928. However, *Carbonita evelinae* has never been found in strata older than Westphalian (Jones, 1870; Jones and Kirkby, 1886a; Scott and Summerson, 1943; Copeland, 1957; Bless, 1973a; Bless and Pollard, 1973). The species described herein is also smaller than is typical for *C. evelinae*, but Bless and Pollard (1973) suggest that maximum size and variability of the carapaces might be related to the occurrence of the form in its typical environment. *Carbonita* has a regular association with non-marine facies, (Scott and Summerson, 1943) and the Newfoundland material occurs in deposits from abnormally saline marine conditions. The details of an inner lamella has never been documented for *C. evelinae*.

Bushmina (1968, 1970) erected *Acutiangulata* on material originally assigned to *Carbonita* (Posner in Tschigova, 1960), and in no description of *Acutiangulata* has a striate ornament



Text-fig. 6.12 : Growth sequence for *Acutiangulata* n. sp. A. from Sub-assemblage IIB.

or the details of the inner lamella been reported.

The assignment of the present material to *Acutiangulata* is based upon three major criteria : 1. the inconsistencies of this material with descriptions of *C. evelinae*, 2. the form of the posterior corner of the right valve; and 3. the form of the inner lamella, which is not unlike that of other bairdiaceans. Striated ornaments have been previously described in other bairdiaceans such as *Tubulibairdia*? spp., (Blumenstengel, 1970, Pl. 11, figs. 29 - 33), therefore its occurrence in species of *Acutiangulata* might not be unexpected.

Superfamily CYTHERACEA Baird, 1850

nom. transl. Ulrich and Bassler, 1923 ex Cytheridae Baird, 1850.

Diagnosis : See Howe in Moore, 1961, p. 254.

Family BYTHOCYTHERIDAE Sars, 1926

nom. transl. Sylvester-Bradley, 1961 ex Bythocytheridae Sars, 1926.

Diagnosis : See Sylverster-Bradley in Moore, 1961, p. 267.

Type-genus : *Bythocythere* Sars, 1866

Stratigraphic range : Devonian to Recent.

Genus *Monoceratina* Roth, 1928

Diagnosis : See Roth, 1928, pp. 15 - 16.

Type-species : *Monoceratina ventrale* Roth, 1928.

Stratigraphic range : Devonian to Recent.

Monceratina youngiana (Jones and Kirkby, 1886)

Pl. 9 figs. 1 - 5

Material : 3 right valves, 1 carapace.

Synonymy : 1886c *Bythocythere youngiana* n. sp. Jones and Kirkby, p. 263, Pl. 9, figs. 4a,b.

1938 *Monoceratina furcula* (n. sp.) Croneis and Gale, p. 260, Pl. 5, figs. 21 - 22.

1947 *Monoceratina furcula* Croneis and Gale, Cooper, Pl. 23, figs. 5 - 8.

1951 *Monoceratina youngiana* (Jones and Kirkby), Posner, p. 27, Pl. 15, fig. 4.

1959 *Monceratina youngiana* (Jones and Kirkby), Robinson, pp. 445, 446, Pl. 1, fig. 6.

1979 *Monoceratina youngiana* (Jones and Kirkby), Robinson, p. 140, Pl. 6, figs. 2a,b.

?1941 *Monoceratina opima* n. sp. Cooper, p. 23, Pl. 1, figs. 29 - 32.

?1974 *Monoceratina* sp. 118 Becker et al., Pl. 7, fig. 8.

Description : Subrhomboidal outline, tumid, dorsal border very slightly arched, ventral border convex and roughly parallels dorsal; cardinal angles obtuse and almost equal. Anterior border more evenly rounded than posterior which is swept up to posterior cardinal angle from posterior ventral border. Plane of maximum length inclined from point of maximum curvature of posterior margin to that of anterior margin. Maximum height just in front of alae Maximum width anterior of alae, tapers backward less steeply than forward, giving broad lanceolate dorsal aspect. Pair of ventral posterior alae represented by posteriorly directed spines just in

front of the posterior upswing. Side of triangular area formed by alae and mid-antero-ventral point define maximum length and width of alae. Alae not seen in dorsal aspect, being situated ventrally of lateral surface. Groove and tongue hinge straight with no obvious overlap. Evidence of duplicature seen in Pl. 9 figs. 1, 3. Pitted, coarse retioulate ornament covers carapace surface, often poorly preserved.

Dimensions :

L	H	W	
500	275	270	Pl. 9 figs. 1 - 5

Locality : NS. 3

Occurrence: Hants County, Nova Scotia; ?Belgium; Podmoscow Basin, Russia; U.K.; Illinois, U.S.A..

Remarks : This species is recorded from the Alexinsky horizon of the Moscow Basin (Posner, 1951), the Brigantian of England (Robinson, 1979), lower Carboniferous of Western Scotland (Young, 1891), and the Kennetcook Limestone of Nova Scotia. The species *Monoceratina furcula* Croneis and Gale, 1939, has been described from the Chesterian of the Mid-Continent (Croneis and Gale, 1938; Cooper, 1947). This form is included in synonymy with *Monoceratina youngiana* because it has similar growth ratio and description. It is seen that *M. youngiana* occurs earlier in the Moscow Basin than it does elsewhere and persists later in the Mid-Continent. It is a rarely occurring species indicative of shallow marine conditions. *Monoceratina opima* Cooper, 1941 has a much more tumid carapace than other specimens of similar length and height, but is in all other respects identical, it is suggested that the form may be a

female of M. *youngiana*.

Monoceratina antiqua (Jones and Kirkby, 1886)

Pl. 8 figs. 8 - 11

Material : 2 steinkerns.

Synonymy : 1886c *Bythocythere antiqua* n. sp. Jones and Kirkby, p. 263, Pl. 9, figs. 5a,b.

1956 *Monoceratina sinuata* n. sp. Posner in Zanina, pp. 194, 195, Pl. 1, fig. 3.

1979 *Monoceratina antiqua* (Jones and Kirkby) Robinson, p. 140, Pl. 6, figs. 4a,b.

?1977 *Monoceratina?* sp. Sohn, p. 150, Pl. 2, fig. 17.

Description : Subrhomboidal outline, tumid, dorsal border slightly arched ventral border convex: cardinal angles obtuse, anterior being more so than posterior. Anterior border broadly rounded and takes form of narrow marginal rim. Posterior border sharply upswept from alae to posterior cardinal angle and also extended into slight rim. Maximum length inclined from posterior cardinal angle to point of maximum curvature of anterior border. Maximum height just posterior to anterior cardinal angle. Maximum width occurs in ventral plane, bisects maximum extension of alae and occurs just anterior of mid-length. Carapace sides arc steeply to dorsal margin. Faint sulcus anterior of alae in lateral view sweeping slightly forward from dorsal border. Stronger posterior sulcus almost confluent with the posterior ends of alae, running almost perpendicular from dorsal border to alae. Alae are supressed as lateral swellings forming ridge that protrudes obliquely downward. In ventral aspect alar outline is flattened diamond shaped area formed by outermost margins of alae and points

of upswing of posterior and anterior margins. Center of ventral plane slightly depressed on either side of valve margins. Hinge straight. Duplicature can be seen in grooves around free margins of steinkern material.

Dimensions :

L	H	W	
725	375	325	Pl. 8 figs. 8 - 11

Locality : Ag. 4

Occurrence: Port au Port Peninsula, western Newfoundland; U.K.; Podmoscow Basin, Russia; Arkansas, U.S.A..

Remarks : This species is larger than *Monoceratina youngiana* which it predates although the upper range of *Monoceratina antiqua* may overlap with the lower range of *M. youngiana* in some areas. *M. antiqua* occurs in the Chadian to Asbian of England (Robinson, 1979), the Tulsky horizon of the Pod Moscow Basin (Zanina, 1956), and the Lower Codroy sediments of western Newfoundland. If *Monoceratina* sp. Sohn is synonymous with *M. antiqua* then the species range is extended to the upper Chesterian of the Mid-Continent. The species is rare and its true global distribution in space and time is not completely known.

Family CYTHERIDEIDAE Sars, 1925

nom. transl. Sylvester-Bradley and Harding, 1953 ex Cytheridinae Sars, 1925

Diagnosis : See Howe in Moore, 1961, p. 272.

Subfamily CYTHERIDEINAE Sars, 1925

Diagnosis : See Howe in Moore, 1961, p. 272.

Type-genus : *Cytheridea* Bosquet 1852.

Stratigraphic range : Carboniferous to Recent.

Genus *Bassilerella* Kellett, 1935

Diagnosis :See Kellett, 1935, pp. 155 - 156.

Type-species : *Bassilerella crassa* Kellett, 1935.

Stratigraphic range : Carboniferous to Permian.

Bassilerella obesa Kellett, 1935

Pl. 9 figs. 6 - 8

Text-fig. 6.13

Material : About 50 steinkerns and carapaces.

Synonymy : 1935 *Bassilerella obesa* Kellett, p. 156, Pl. 17, figs. 6a - f.

?1973 *Acratia* sp. Blassyk and Natusiewicz, pp. 133, 134, Pl. 29, figs. 3a - d.

Not 1946 *Bassilerella obesa* Kellett, Cooper, P. 69, Pl. 9 figs. 5 - 7.

Description : Carapace short sub-triangular in outline. Dorsal margin broadly convex, cardinal angles indistinct. Hinge straight about 1/3 length, slightly impressed. Dorsal margin slopes steeply to anterior margin, which is more bluntly rounded than posterior margin. Posterior slope shallower and posterior extremity low, acuminate and slightly pointed. Venter weakly convex curves gently upward to ends. Maximum length just above venter and bisects extremities. Maximum height forward of mid-length at site of

maximum dorsal bend. Maximum width equal to, or greater than, maximum height and situated below mid-height in plane of maximum height. Carapace is tumid in dorsal view, pointed at extremities. Left over right overlap and inner lamella seen on steinkern material.

Dimensions :

L	H	W	
875	450	500	Pl. 9 figs. 6 - 8

Locality : Ag. 1, Ag. 2, Ag. 4, Ag. 5.

Occurrence: Port au Port Peninsula of western Newfoundland and Kansas.

Remarks : Six instar groupings can be discriminated on the scattergram (Text-fig. 6.13).

Bassilerella firma Kellett, 1935

Pl. 10 figs. 1 - 6

Text-fig. 6.14

Material : About 850 carapaces and steinkerns.

Synonymy : 1935 *Bassilerella firma* Kellett, pp. 156, 157, Pl. 17, figs. 5a - g.

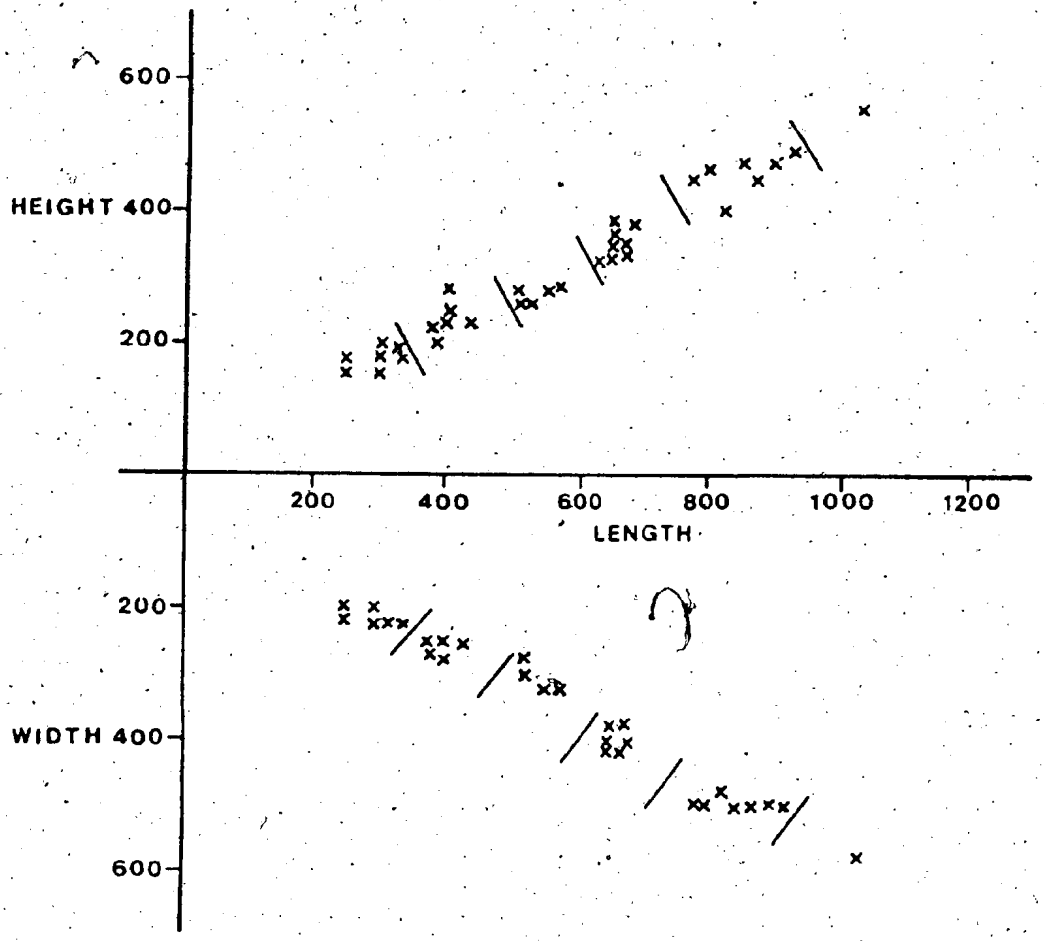
1946 *Bassilerella firma* Kellett, Cooper, p. 69, Pl. 9, figs. 1, 2.

1977 *Bassilerella?* sp. A. Requadt et al., p. 94, Pl. 7, figs. 6 - 9.

?1946 *Bassilerella obesa* Kellett, Cooper, p. 69, Pl. 9, figs. 5 - 7.

?1946 *Bassilerella acuminata* Kellett, Cooper, P. 69, Pl. 9, figs. 8 - 10.

?1981 *Acratia (C?)* sp. 8. Lethiers, P. 85, Pl. 18, fig. 173.



Text-fig. 6.13 : Growth sequence for *Bassleriella obesa* Sub-assemblage IIB.

Description : Carapace essentially similar to *Bassleriella obesa*, however, major difference is greater elongation of carapace and reduced maximum width. Posterior dorsal slope has more pronounced angular bend than *B. obesa*, and posterior end less acuminate.

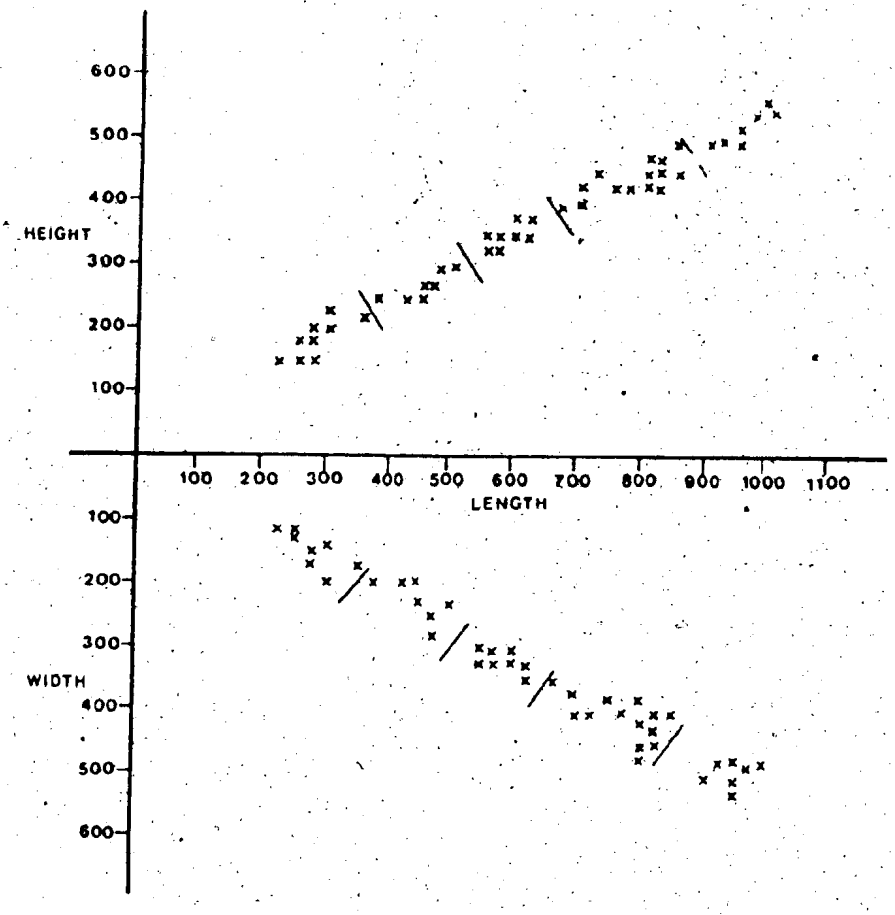
Dimensions :

L	H	W		
950	500	525	Pl. 10	figs. 1 - 3
725	450	400	Pl. 10	figs. 4 - 6

Locality : Ag. 1, Ag. 2, Ag. 4, Ag. 5, Ag. Bk. 2, Ag. Bk. 3, Ag. Qu. 1. CC. 9

Occurrence: Western Newfoundland; Illinois, U.S.A.; Pyrenees, Spain; ?Belgium.

Discussion : *Bassleriella* is a rarely reported genus and has an imperfectly known stratigraphic range. The genus has hitherto only been reported from Pennsylvanian and Westphalian strata (Kellett, 1936; Scott and Borger, 1941; Cooper, 1946; Brondos and Kaesler, 1976; Redquadt et al., 1977; Haack and Kaesler, 1982). Redquadt et al. (1977) suggest that the Dinantian ostracode "Bairdiid ostracode sp. 121" Becker *et al.* 1974 may be a form of *Bassleriella*, but from the photographs alone (Becker et al., 1974, Pl. 8, figs. 2, 3) it is not possible to determine whether this is so. It may be that further research on this genus will reveal a closer relationship to the bairdiaceans than is presently suggested. *Bassleriella* is most similar to *Acratia* in general outline, however it is less acuminate, and although the antero-ventral margin may be swept upwards, it lacks the pronounced concavity of *Acratia*.



Text-fig. 6.14 : Growth sequence for *Bassleralla firma* from Sub-assemblage IIB.

Suborder PLATYCOPINA Sars, 1866

nom. correct. Sylvester-Bradley in Moore, 1961 pro Platycopa Sars, 1866.

Superfamily KLOEDENELLACEA Ulrich and Bassler, 1908

Family KLOEDENELLIDAE Ulrich and Bassler, 1908

Diagnosis : Sulcate, subrhomboidal kloedenellaceans, commonly with right over left overlap. Largest valve possesses a stragulum in antero-dorsal margin and hinge-line posterior to it i.e. kloedenellid hinge of Adamczak (1966, pp. 11 - 13; 1968, pp. 16, 17). Straight to convex dorsal margin. (Adapted from Becker and Sanchez de Posada, 1977, p. 143).

Remarks : For discussion of the assignment of Kloedenellacea to Platycopina see Adamczak (1966, pp. 13, 14).

Type-genus : *Kloedenella* Ulrich and Bassler, 1908.

Stratigraphic range : (?Upper Ordovician) lower Silurian to Pennsylvanian (?Permian)

Genus *Neokloedenella* Croneis and Funkhouser, 1939

(syn. *Lochriella* Scott, 1942, *Indivisia* Zaspelova in Egorov, 1954)

Diagnosis : See Croneis and Funkhouser, 1939, p. 341.

Type-species : *Neokloedenella prima* Croneis and Funkhouser, 1939.

Stratigraphic range : (?Devonian) Carboniferous.

Remarks : There is a need for a monographic study of the whole superfamily Kloedenellacea, until that is done, the status of

several genera is in doubt. *Neokloedenella* Croneis and Funkhouser, 1939, was placed in questioned synonymy with *Oliganisus* Geis, 1932, by Scott (in Moore, 1961, p. 182). The more distinct angularity of the carapace, the posterior furrow and possibly the punctate ornament (Geis, 1932, p. 159), may serve as distinguishing criteria. In this study the genus *Indivisia* Zaspelova in Egorov, 1954, is taken to be a junior synonym of *Neokloedenella*, despite the fact that no internal partition has been found in the latter. It is recognised that this could be a function of the lack of mature female valves in this collection. In all other aspects the two genera would appear to be identical. *Ellipsella* Coryell and Rogatz, 1932, is very similar to *Neokloedenella* and the lack of a sulcus (Coryell and Rogatz, 1932, p. 390) does not militate against a close relationship or even synonymy of the two genera, since specimens in the present study do not always possess a sulcus. Without further study of all these genera it is not possible to be dogmatic as to their true relationships.

"Neokloedenella" variolata (Zanina, 1960)

Pl. 11 figs. 1 - 8

Text-fig. 6.15

Material : About 450 carapaces and 20 valves.

Synonymy : 1960 *Indivisia variolata* Zanina, p. 85, Pl. 7, figs. 5, 6.
1968 *Indivisia variolata* Zanina, Jones, p. 35, Pl. 4, figs. 1 - 5.

Description: Carapace smooth, ovate to subrectangular in outline, with slightly convex dorsal margin, indistinct cardinal angles

and medianally concave venter. Postero-ventral margin sweeps upward more steeply to posterior end than anterior end. Both extremities are subequal and broadly rounded. Weak dorso-median tear-drop shaped sulcus, deepest at mid-height. Left valve smaller than right and overlapped most noticeably at posterior margin. Maximum height posterior and maximum length above mid-height. Maximum width posterior, giving elongated triangular dorsal outline. Posterior end square and anterior end rounded. Antero-dorsal stragulum with process of right valve overlapping left.

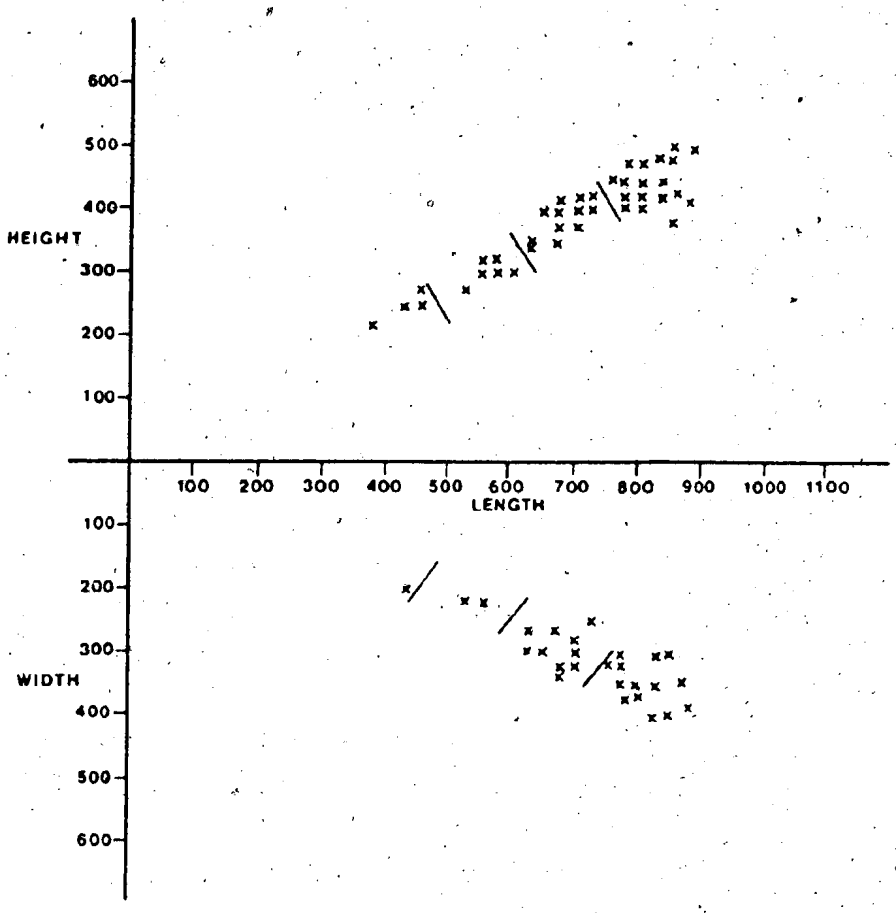
Dimensions :

L	H	W		
850	475	400	Pl. 11	figs. 7, 8
850	425	-	Pl. 11	figs. 5, 6
825	450	250	Pl. 11	figs. 1 - 4

Localities : B. 1, B. 2, Ag. 2, Ag. 4, Ag. 5, Mi. 1
SC. Nodo 3, SC. Nodo. 8, SC. Nodo. 9,
CR. Nodo. 3, CR. Nodo. 4, Bk. 1, CC. 6, CC, 7, Wo. 10
NS. 4

Occurrence: Southwestern Newfoundland; Antigonish County, Nova Scotia; Australia; and the Russian Platform.

Remarks : There are 4 instars shown in the scattergram (Text-fig. 6.15). This species can be differentiated from *Neokloedenella prima* Croneis and Funkhouser, 1939, by the more quadrate outline of *N. prima* and the more upswept posterior margin of *Neokloedenella variolata*.



Text-fig. 6.15 : Growth sequence for "*Neokloedenella*" from Assemblage V.

Family GEISINIDAE Sohn, 1961

Diagnosis : See Sohn in Moore, 1961, p. 182

Genus *Geisina* Johnson, 1936

Diagnosis : See Johnson, 1936, pp. 21, 22.

Type-species : *Jonesina gregaria* Ulrich and Bassler, 1906.

Stratigraphic range : Devonian to Permian.

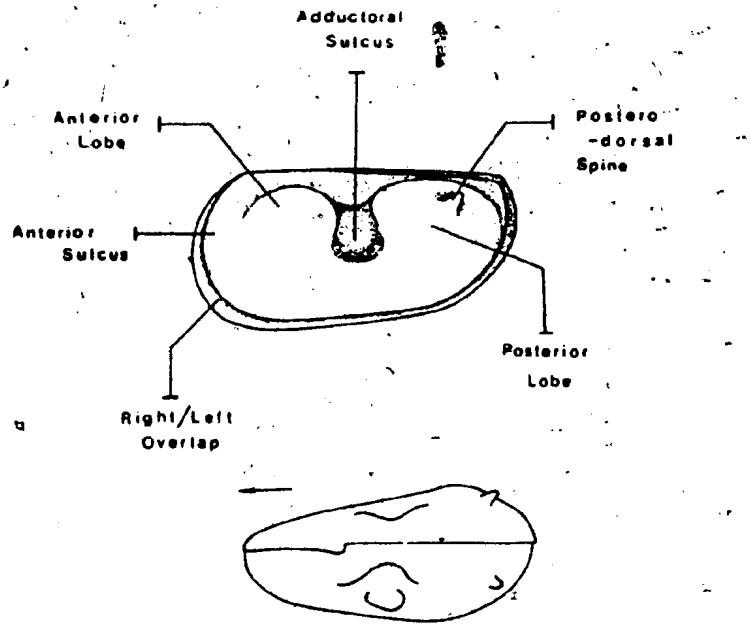
Geisina sp.

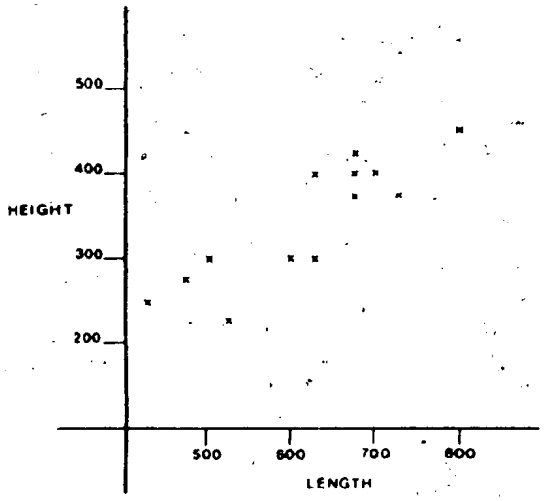
Pl. 10 figs. 7 - 9

Text-fig. 6.16

Material : 12 poorly preserved carapaces and 4 valves.

Description : Carapace smooth, subrhomboidal, bilobate, with straight dorsal margin. Cardinal angles obtuse, anterior angle more so than posterior, which is about 95°. Anterior border more broadly rounded than posterior which sweeps down into inclined, straight ventral margin. Maximum height at anterior cardinal angle, maximum length inclined from posterior cardinal angle antero-ventrally about twice height. Maximum width in posterior 1/3 of carapace and corresponds to broadest tumidity of posterior lobe. Carapace tapering wedge shaped in dorsal aspect, with bulbous posterior. Right valve larger than left and overlaps around free margins and along posterior half of dorsal margin. Left valve impressed into region of overlap. Hinge-line stepped toward left valve in anterior portion and curves gently from step to anterior angle, being a typical stragulum (Text-fig. 6.16).





Text-fig. 6.16 : Morphology and growth sequence of *Geisina* sp. from Assemblage V.

Lobes confluent ventrally but separated dorsally by deep sulcus. Sulcus situated in front of mid-line, widens ventrally and possesses pinched neck giving circular drop shape. Posterior lobe surmounted by short spine, located in uppermost corner of lobe pointing up and obliquely outward from dorso-posterior region. Anterior lobe less tumid, less distinct and bounded by indistinct sulcus. Anterior lobe may be formed by the confluence of L1 and L2, since hints of prenodal sulcus (S1) invaginate dorsal portion of lobe.

Dimensions :

L	H	W		
725	375	260	Pl. 10	fig. 8
700	400	275	Pl. 10	fig. 7
675	400	350	Pl. 10	fig. 9

Locality : CC. 6, Wo. 5, CR. Nodo. 4

Occurrence: Southwestern Newfoundland.

Remarks : The specimens of this collection indicate that four instars are present, and juveniles rarely possess a spine (Text-fig. 6.16). The genus *Geisina*, as presently defined (Sohn in Moore, 1961) is based upon the presence of the dorso-posterior spine. Sohn (1969, p. 46) and Anderson (1970, p. 75) suggest that this criterion is too superficial for defining generic rank, and most Russian works use genus *Jonesina* for forms akin to either *Geisina* or *Hypotetragona* (Posner, 1951; Bushmina, 1968). McGill (1962, pp. 5, 6) suggested for *Hypotetragona albertensis* that the ontogenetic series of *Geisina*-like instars gave rise to a *Hypotetragona*-like adult, which is further evidence that the spine might not be of generic significance. It is also reasonable to

assume that forms lacking the spine could have lost them through the processes of preservation and even sample preparation.

Family BEYRICHIOPSIDAE Henningsmoen, 1953

nom. transl. Sohn in Moore, 1961 ex Beyrichiopsinae Henningsmoen, 1953.

Diagnosis : See Sohn in Moore, 1961, p. 185.

Genus *Beyrichiopsis* Jones and Kirkby, 1886

Synonymy : See Green, 1963, p. 90.

Diagnosis : See Green, 1963, p. 91.

Type-species : *Beyrichiopsis fimbriata* Jones and Kirkby, 1886b.

Stratigraphic range : Upper Devonian to upper Mississippian.

Beyrichiopsis cornuta Jones and Kirkby, 1886

Pl. 13 figs. 1 - 3

Text-fig. 6.17

Material : One single carapace.

Synonymy : 1886d *Beyrichiopsis cornuta* Jones and Kirkby, p. 436, Pl. 11, fig. 11.

1908 *Beyrichiopsis cornuta* Jones and Kirkby, Ulrich and Bassler, p. 323, Pl. 43, fig. 29.

1932 *Beyrichiopsis cornuta* Jones and Kirkby, Latham, p. 365.

1959 *Beyrichiopsis cornuta* Jones and Kirkby, Robinson, p. 439, Pl. 2, figs. 7a,b.

Description : Bilobate, unisulcate, ovate-oblong outline, with very narrow right over left overlap. Dorsal border about 3/4 maximum length. Maximum height occurs at anterior cardinal angle and maximum length occurs at mid-height, maximum width occurring in the posterior lobe. Hinge straight with stragulum in anterior 1/3. and second notch above posterior lobe. Cardinal angles about 130°, posterior angle about 5° larger than anterior. Ventral border straight curves gently upward into broadly rounded anterior and posterior margins, is very slightly indented in front of posterior lobe. Anterior margin more broadly rounded than posterior. Crenulate frill around free margins with pronounced denticles in anterior portion and almost devoid of crenulations in ventral region. Frill begins with node about 100 microns from anterior cardinal angle terminates in less obvious node just before posterior cardinal angle. U-shaped sulcus situated in front of mid-length, deepest dorsally of mid-height, shallows and broadens dorsally. Poorly defined ventral lobe occurs below mid-height and terminates in front of posterior lobe. Anterior lobe likewise poorly defined, whereas prominent posterior lobe is situated high on valve behind mid-length, and surmounted by strong tubercle. Surface of carapace smooth, devoid of carinae.

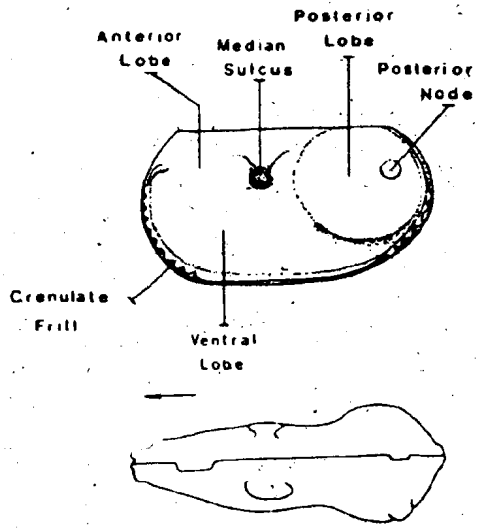
Dimensions :

L	H	W	
810	430	350	Pl. 13 figs. 1 - 3

Locality : NS. 3

Occurrence: Hants County, Nova Scotia, U.K..

Remarks : This very distinctive form of *Beyrichiopsis* Jones and Kirkby has not been described frequently in the literature although Robinson (1959) states that it is fairly abundant in the Holkerian and Asbian. It has not been reported outside the British Isles, however, it shows great similarity to *Beyrichiopsis spinosa* (Croneis and Bristol, 1939 p. 73, Pl. 3, fig. 21) and the closely related forms *Beyrichiopsis serrata* (Croneis and Thurmann, 1939, pp. 307, 308, Pl. 7, figs. 7 - 10) and *Beyrichiopsis tumida* (Cooper, 1941, p. 54, Pl. 11, figs. 13, 14) from the Chesterian of Illinois. Green (1963, p. 94, Pl. 3, figs. 14 - 26) described *Beyrichiopsis bispinosa* which shows affinity to the Chesterian species. Until the type material of all these species is investigated their relationships will remain uncertain.



Text-fig. 6.17 : Morphology of *Beyrichiopsis cornuta*.

Beyrichiopsis lophota Copeland, 1957

Pl. 12 figs. 1 - 5

Text-fig. 6.18

Material : About 260 carapaces and valves.

Synonymy : 1957 *Beyrichiopsis lophota* Copeland, p. 32, Pl. 3, figs. 1 - 8

Description : Carapace ovate subrectangular outline bilobate with slightly convex dorsal margin and convex ventral margin. Cardinal angles distinct, posterior angle about 90°, anterior angle about 130°. Posterior margin square and anterior margin broadly rounded. Maximum height just posterior of anterior cardinal angle, maximum length in plane of mid-height. Carapace ellipsoid in dorsal view. Maximum width posterior of median sulcus. Median dorsal sulcus pit-like, deepest in lowest portion, shallow and broader in the dorsal region. 4 marginal carinae present. Most extreme dorsal carina runs parallel to dorsal margin and gives impression of depressed hinge. Dorsal marginal carina continuous with marginal frill, which runs sub-parallel to valve margins and most strongly developed on right valve. Extreme ventral carina runs just outside of marginal frill, along ventral margin, does not continue into posterior or anterior margins. Two remaining longitudinal carinae are sub-parallel to valve margins, slope anteriorly, situated on latero-dorsal and latero-ventral portions of valve. Latero-dorsal carina starts at top of posterior lobe, crosses narrowest point of median sulcus and turns ventrally around top of anterior lobe. Latero-ventral carina starts at bottom of posterior lobe, swings ventrally and turns slightly up to lower

anterior edge of anterior lobe. Neither of these carinae meet nor reach valve margins. Carapace finely reticulated.

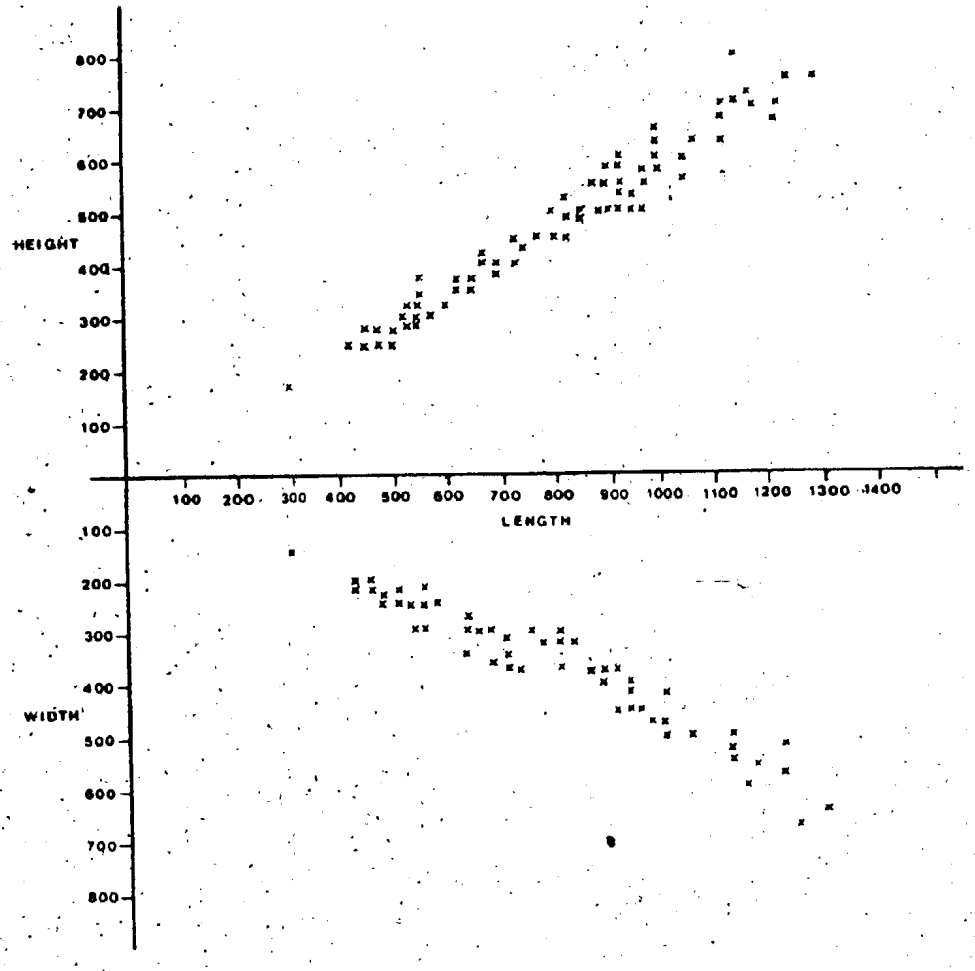
Dimensions :

L	H	W	
900	500	450	Pl. 12 figs. 1 - 5

Locality : NS. 5, NS. 6

Occurrence: Hants County, Nova Scotia.

Remarks : Instars are poorly defined in the dispersal diagram (Text-fig. 6.18) This species is most closely allied to *Beyrichiopsis plicata* Jones and Kirkby, 1885. Figured specimens of *B. plicata* (Jones and Kirkby, 1885b, Pl. 3, figs. 9, 10, 1886b, Pl. 7, figs. 1a,b, 2, 3a,b; and Robinson, 1978, Pl. 4, figs. 5a,b) indicate that the two central longitudinal carinae are commonly looped anteriorly, but that this is not a consistent feature. In specimens of *Beyrichiopsis lophota* the carinae are never looped and this feature can be used to differentiate the two forms. In specimens of *B. plicata* where the carinae do not meet, they are not so widely separated as in *B. lophota*. Geldsetzer et al. (1980) state that the most abundant ostracode in the Wentworth Quarry sections (samples NS. 5, NS. 6) is *Glyptopleura paracostata*, it is assumed that the species is supposed to be *Glyptopleura parvacostata* Geis, 1932, which is a synonymy of *B. plicata*.



Text-fig. 6.18 : Growth sequence for *Beyrichiopsis lophota* from Assemblage IV.

Family uncertain

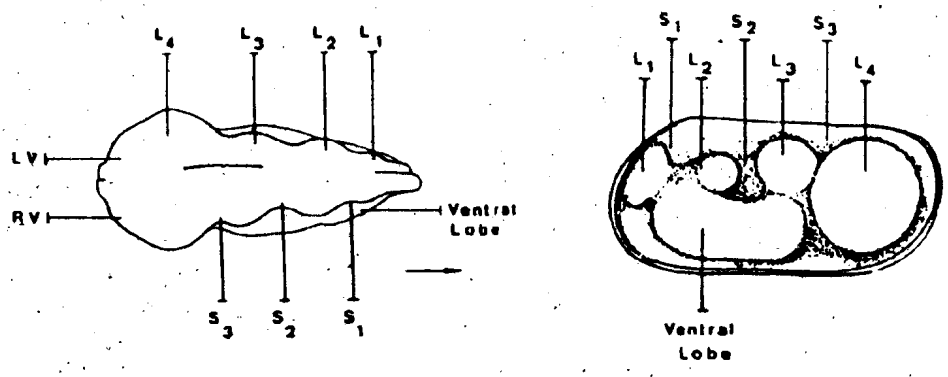
gen. et sp. indet. 1

Pl. 13 figs. 4 - 6

Text-fig. 6.19

Material : 1 single silicified, almost completely exfoliated steinkern.

Description : Elongate, subquadrilobate, trisulcate carapace with straight dorsal and ventral margins. Posterior cardinal angle slightly greater than 90°, and anterior cardinal angle approaches 120°. Anterior margin broadly rounded but maximum curvature occurs below mid-height. Posterior margin more evenly rounded. Plane of maximum length inclined from point of maximum curvature of posterior margin to that of anterior margin. Maximum height not defined due to poor preservation of specimen. Posterior lobe large, well developed and at site of maximum width. L1, L2, L3, progressively smaller and less clearly defined, L1 almost completely confluent with ventral lobe, which is also confluent with lower edges of L2 and L3, but not confluent with L4. Median sulcus, S2 deeper and longer than others, occurs forward of mid-length, and peters out at ventral lobe. S1 short and shallow and terminates at antero-dorsal and postero-dorsal edges of ventral lobe; whereas S3 passes from dorsal margin, anterior of L4 and posterior of ventral lone, to ventral margin. Right valve is larger than left. Details of surface ornament and hinge structures unknown. (Text-fig. 6.19).



Text-fig. 6.19 : Morphology of kloedenellacean gen. et sp. indet. 1.

Dimensions :

L	H	W	
710	350?	325	Pl. 13 figs. 4 - 6

Locality : Crabb. 2-2

Occurrence: Southwestern Newfoundland.

Remarks : The carapace is kloedenellacean in form, however without details of hinge structures, this fact cannot be substantiated. The description is similar to that of *Jonesina fastigiata* (Jones and Kirkby), (Jones and Kirkby, 1886, p. 438, Pl. 12, figs. 8 - 10) and *Jonesina fastigiata* var. *spinosa* Posner (Zanina, 1956, p. 200, Pl. 2, figs. 1a - c). According to the Treatise (Moore, 1961, p. 413) *Jonesina* Ulrich and Bassler, 1908, is a *nomem dubium*. Ulrich and Bassler (1908, p. 324), state that *Jonesina* can be variously lobed with as many as three nodes sited anterior of the main sulcus (S2), in the more complex forms, such as *J. fastigiata*. The specimen has a vertical sulcus

anterior of L4 which opens ventrally, this is a character considered to be diagnostic of the genus *Kloedenelletina* Egorov, 1950 (Sohn in Moore, 1961, p. 168). In this respect it is similar to *Kloedenelletina sygmoeformis* (Batalina), however the lobation is more complex.

The specimen quite probably represents a new genus, but without further material a diagnosis cannot be made.

Suborder METACOPINA Sylvester-Bradley, 1961

Superfamily HEALDIACEA Harlton, 1933

nom. transl. Mandelstam, 1960, ex Healdiidae Harlton, 1933

Family HEALDIIDAE Harlton, 1933

Diagnosis : See Shaver in Moore, 1961, pp. 359 - 361.

Genus *Healdia* Roundy, 1926

Diagnosis : See Shaver in Moore, 1961, p. 361.

Type-species : *Healdia simplex* Roundy, 1926.

Stratigraphic range : Devonian to Permian.

Healdia sp?

Pl. 14 figs. 1 - 7

Text-fig. 6.20

Material : about 80 steinkerns.

Description : Carapace is very small, subtriangular, with high arched dorsum and slightly concave ventrum. Antero-dorsal margin

slopes gently to anterior extremity which is narrow evenly rounded, and sweeps upward quite steeply from antero-ventral margin. Postero-dorsal slope shorter, and posterior extremity broadly rounded, curving evenly into ventral margin. Maximum height occurs posterior of mid-length at point of maximum dorsal arching. Maximum length above mid-height, parallel to venter and bisects anterior extremity. Maximum width at mid-length, giving narrow lanceolate dorsal view, with more pointed posterior than anterior end. Left valve overlaps tight especially along anterior margins and less prominantly along mid-ventral margin. A small circular muscle spot in most specimens, high S.E.M. magnification studies of area did not elucidate scar pattern. No signs of a posterior ridge or spines, this is a function of steinkern preservation.

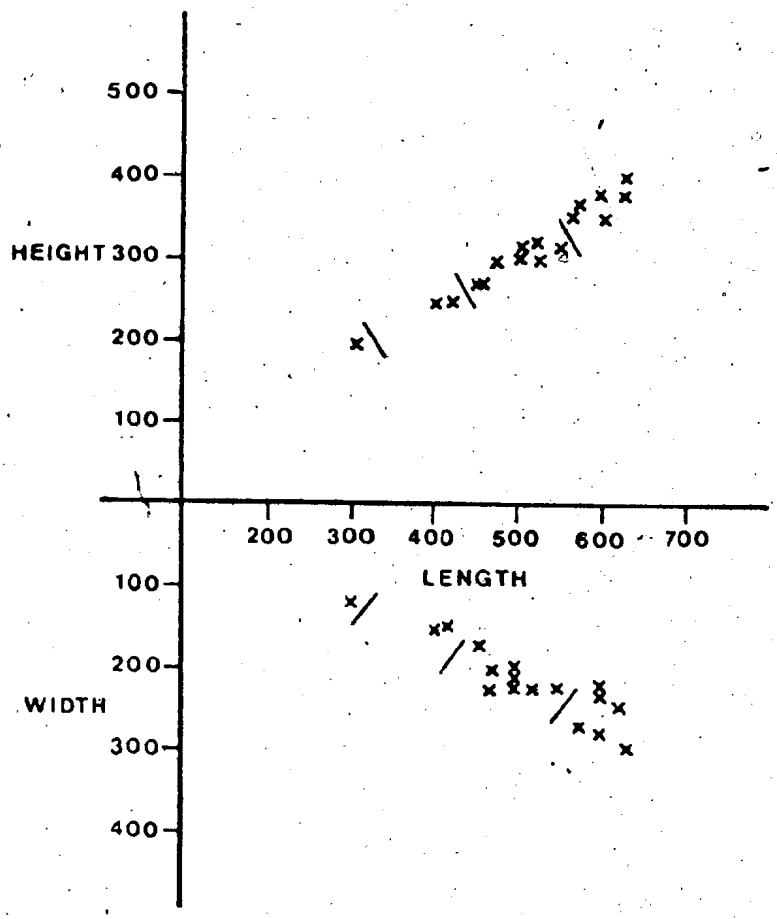
Dimensions :

L	H	W		
625	400	250	Pl. 14	figs. 2, 3
575	350	275	Pl. 14	fig. 1
475	325	275	Pl. 14	figs. 4 - 7

Locality : Ag. 2, Ag. 4, Ag. 5, Mi. 1

Occurrence: Port au Port Peninsula, western Newfoundland.

Remarks : There are 4 instar groupings seen on the scattergram (Text-fig. 6.20). This form is most similar to *Healdia simplex* Roundy, 1926, which is described as being small and often lacking spines (Roundy,1926, p. 8; Kellett, 1935, p. 142) The dorso-posterior margin appears to be shorter and the maximum width is often closer to mid-carapace than is typical of *H. simplex*. *Healdia asymmetrica* (Grundel, 1975) lacks spines as does *H. simplex*, however, a posterior ridge is present. The anterior margin is



Text-fig. 6.20 : Growth sequence for *Healdia* sp.? from Sub-assemblage IIB.

described as being narrower in lateral view than the posterior margin, (Grundel, 1975, p. 975, Pl. 1, fig. 18). *Incisurella foveata* Grundel, 1975, also shows this feature, and in lateral outline is almost identical to *Healdia* sp.?, with the exception of the slight ventral concavity shown by the latter (cf. Grundel, 1975, pp. 972, 973, Pl. 1, figs. 13, 14). The posterior ornament of *Incisurella* Cooper, 1941, differs from that of *Healdia* Roundy, 1926, by the fact that a shallow subovate pit is developed anterior of the posterior margin in the former genus as opposed to paired spines in the latter (Cooper, 1941, p. 33). Since the shell of *Healdia* is quite thick, it is possible that a surface feature may not be seen on the interior surface of the shell (Bless and Massa, 1982, p. 37, figs. 16b, 20b, 21b) and would therefore not be preserved on steinkern material. It is impossible to be certain of the generic assignment of this, though it shows a distinct affinity to *Healdia*.

Family BAIRDIOCYPRIDIDAE Shaver, 1961

Diagnosis : See Shaver in Moore, 1961, pp. 364, 365

Type-genus : *Bairdiocypris* Kegel, 1932.

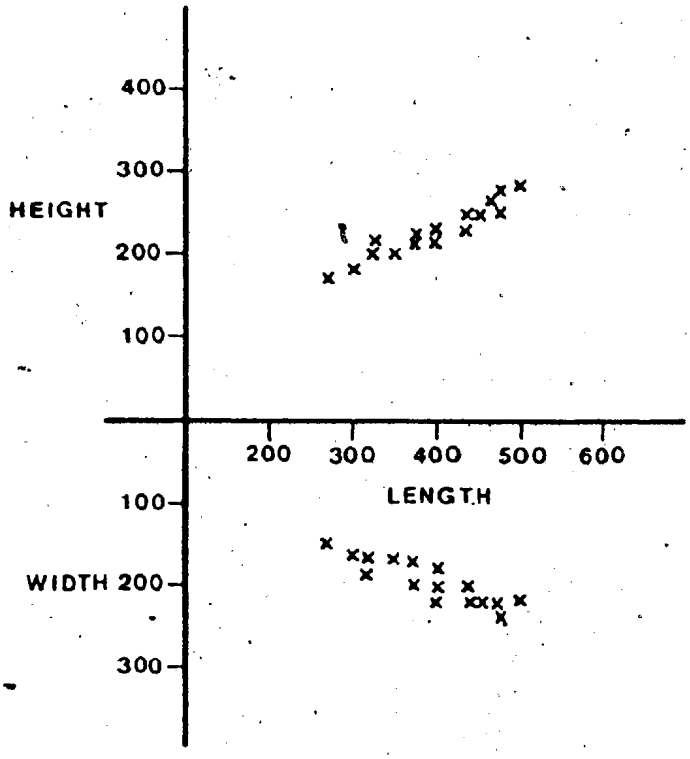
Stratigraphic range : (?Ordovician) Silurian to Permian (?Jurassic)

gen. et sp. indet. 2

Pl. 14, figs. 8 - 11

Text-fig. 6.21

Material : About 180 steinkerns.



Text-fig. 6.21 : Growth sequence for bairdiocypridid gen. et sp. indet. 2 from Sub-assemblage IIB.

Description : Very small elongate subovate carapace, with convex dorsum and straight to concave ventral margin. Cardinal angles indistinct, hinge short and straight and anterior dorsal slope longer and straighter than posterior slope. Anterior margin slightly acuminate rounded and below mid-height. Antero-dorsal margin slopes toward venter and rounds off into anterior extremity. Posterior margin evenly rounded and point of maximum curvature situated at mid-height. Maximum height anterior of mid-length, normally close to anterior cardinal angle where antero-dorsal slope begins. Maximum length inclined from point of maximum curvature, at or above mid-height of posterior margin, to point of maximum curvature, below mid-height at anterior margin. Maximum width posterior of mid-length and carapace subcuneate in dorsal view, with rounded extremities. Right valve overlapped by left, around antero-dorsal margin, less so in posterior margins.

Dimensions :

L	H	W	
475	275	225	Pl. 14 figs. 8 - 11

Locality : Ag. 2, Ag. 5, Ag. Qu. 1, Mi. 1, CC. 7, NS. 3, NS. 4.

Occurrence: Port au Port Peninsula and southwestern Newfoundland, and Hants and Antigonish Counties, Nova Scotia.

Remarks : The general outline of the steinkerns is similar to *Healdianella darwinuloides* Posner, 1951, especially in respect of the long antero-dorsal slope, slight ventral concavity and outline of the posterior and anterior margins. The form is also similar to *Healdianella* vel. *Bairdiocypris* juv., described by Coen (1982, p. 288, fig. 8), but there are no accompanying illustrations and the description is incomplete. Without shell

material and details of the muscle scars it is impossible to assign this material to a genus.

Suborder indet.

Discussion : See section 6.2.1

Superfamily PARAPARCHITACEA Scott, 1959

Diagnosis : See Sohn, 1971, p. 5.

Family PARAPARCHITIDAE Scott, 1959

Diagnosis : See Scott, 1959, p. 673

Remarks : The generic classification used herein follows that of Sohn (1971). For major criteria used to differentiate genera and species see Text-fig. 6.22.

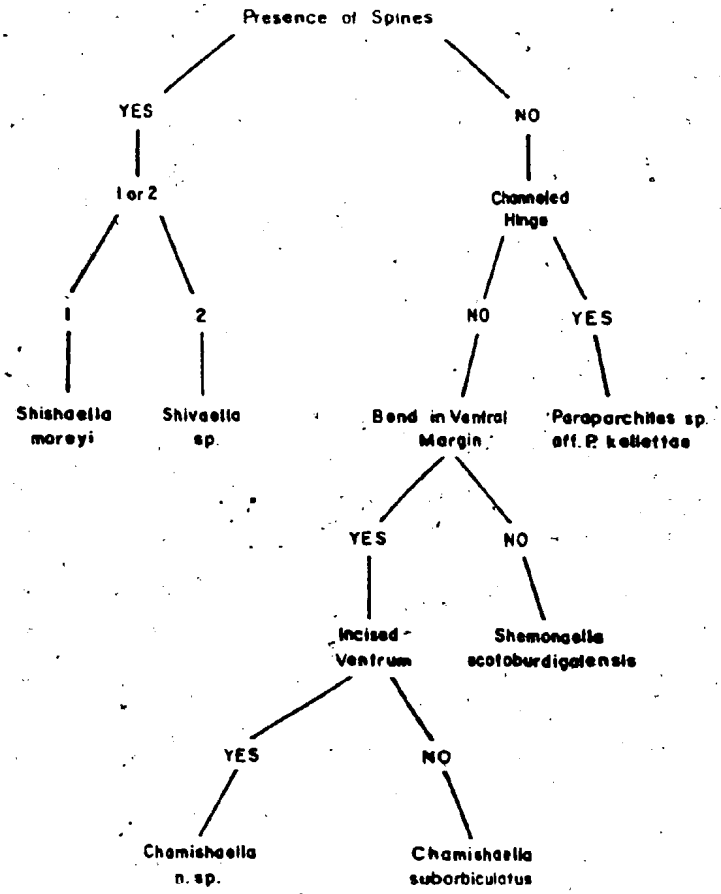
Genus *Paraparchites* Ulrich and Bassler, 1906

Synonymy : See Sohn, 1971, p. 5.

Diagnosis : Outline subovate to elongate ovate smooth, broadly rounded ends. Dorsum straight to slightly convex, hinge chanelled with no significant over-reach of dorsal margin. Left valve overlaps right around free margins. Females broader posteriorly, males with median maximum width. (Adapted from Scott, 1959 and Sohn, 1971).

Type-species : *Paraparchites humerosus* Ulrich and Bassler, 1906.

Stratigraphic range : Devonian to Permian.



Text-fig. 6.22 : Key used in the classification of paraparchitacean ostracodes.

Paraparchites sp. aff. *P. kellettae* Sohn, 1971

Pl. 15 figs. 3 - 7, Pl. 16 figs. 1 - 5

Pl. 17 figs. 1 - 5

Text-fig. 6.23

Material : About 650 partial steinkerns, carapaces and valves.

Description : Smooth subovate carapace, with posterior margin slightly narrower than anterior in lateral view. Dorsal and ventral margins gently convex. Cardinal angles obtuse. Hinge straight and channeled between dorsal ridges of each valve. Dorsal ridges terminate before cardinal angles. Maximum height at mid-length. Maximum length at mid-height and maximum width just above mid-height. Outline ellipsoid in dorsal aspect. Left valve narrowly overlaps right around free margins; right valve may have a very slight dorsal over-reach. One internal mould (Pl. 16 figs. 1 - 5). Shows wide inner lamella. Muscle scar area of steinkern consists of large circular main area, with secondary, deep luneate area below and in front of main field. Muscle scar field situated just below mid-height and slightly anterior of mid-length. No individual fleks seen on detailed examination of muscle scar field. Also on steinkern, dorsal ridge smoothly contours into antero-dorsal margin whereas posterior end of ridge is more abrupt, forming concave step with postero-dorsal valve margin.

Dimensions :

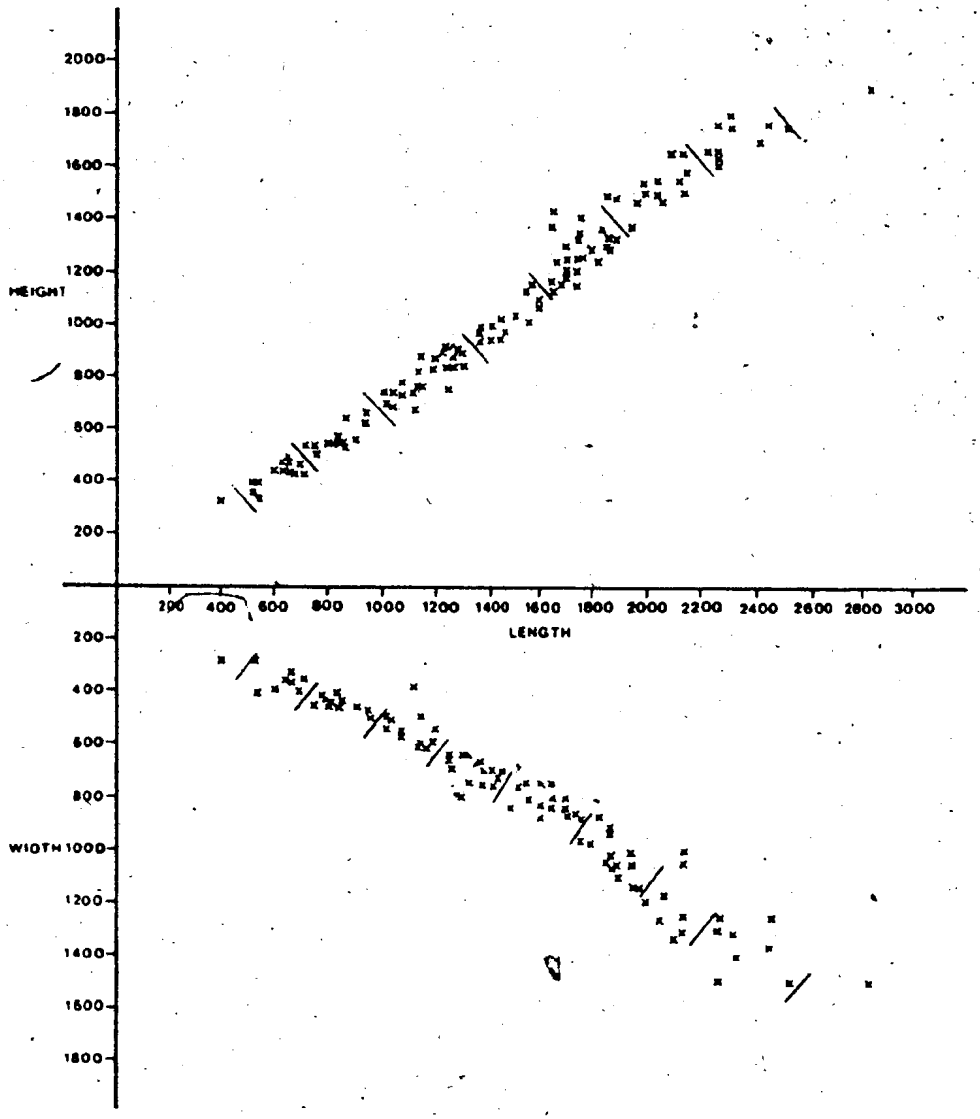
L	H	W		
2475	1750	1250	Pl. 16	figs. 1 - 5
2125	1550	1050	Pl. 15	figs. 3 - 7

Localities : Ag. 2, Ag. 4, Ag. 5

NS. 5, NS. 6

Occurrence: Port au Port Peninsular, western Newfoundland; Hants County, Nova Scotia.

Remarks : The scattergram (Text-fig. 6,23) indicates that there are 7 instars present in the collection, and that fully matured adults are rare. Most specimens show some degree of exfoliation, of one or more layers of the shell. In the Nova Scotia material several of the more complete specimens are filled with a soft white platey mineral, which is thought to be gypsum. The calcitic shell appears to be made of at least two layers of perpendicular needles (Pl. 17, figs. 1 - 5), similar in style to those shown by Rosenfeld (1970, p. 356, fig. 3A) The shape of the carapace is similar to that of *Paraparchites kellettae* Sohn, 1971, which is described from the ?Pennsylvanian and Permian of Kansas and Nebraska (Kellett, 1933, p. 64; Sohn, 1971, p. 8), however the dorsal ridge appears to be more pronounced in this material than in any previously described species of *Paraparchites*. *Paraparchites gibbus* Bell, 1929, described from the lower Windsor of Nova Scotia, lacks a chanelled hinge (Bell, 1929, p. 185, Pl. 34, figs. 6, 6a,b) is referred to *Chamishaella* due to the pronounced dorsal overlap and straight or gently convex dorsal margin.



Text-fig. 6.23 : Growth sequence for *Paraparchites* sp. aff. *P. kellettae* from Assemblage IV.

Genus *Shemonaella* Sohn, 1971

Diagnosis : Paraparchitid lacking spines, and an incised dorsum, with no signigicant bend along ventral margin (Adapted from Sohn, 1971, p. 16).

Type-species : *Shemonaella dutroi* Sohn, 1971

Stratigraphic range : (Middle Devonian) Mississippian to Pennsylvanian.

Shemonaella scotoburdigalensis (Hibbert, 1836)

Pl. 15 figs. 1 - 2

Text-fig. 6.24

Material : 45 steinkerns and 12 pyritised partial and complete carapaces.

Synonymy : 1836 *Cypris scotoburdigalensis* Hibbert, p. 179.
1884 *Leperditia scotoburdigalensis* (Hibbert) Jones, pp. 314 - 316, 321, 324, Pl. 2, figs. 7, 9.
1884 *Leperditia okeni* var. *scotoburdigalensis* (Hibbert) Jones and Kirkby, p. 357, Pl. 12, figs. 1,2.
1886c *Leperditia scotoburdigalensis* (Hibbert) Jones and Kirkby, p. 254, Pl. 7, figs. 4a,b.
1896 *Leperditia scotoburdigalensis* (Hibbert) Jones and Kirkby, pp. 180, 181, Pl. 11, fig. 12.
1933 *Paraparchites scotoburdigalensis* (Hibbert) Latham pp. 354, 355, fig. 2.
1960 *Limnoprimitia? hortonensis* Bell, pp. 41, 42, Pl. 19, figs. 1 - 8..
1974 *Shemonaella?* sp. cf. 66 Becker and Bless, Becker et al., p. 52, Pl. 7, fig. 9
1978 *Shemonaella scotoburdigalensis* (Hibbert) Robinson, p. 148, Pl. 10, figs. 4a,b.
?1974 *Shemonaella?* sp. 66 Becker and Bless, Pl. 19, fig. 3.
?1974 *Chamishaella kaisini* Rome, pp. 335 - 338, figs. 34 - 36.

For an extended list of unfigured descriptions see Bell (1960, p. 41) Jones and Kirkby (1896, pp. 180, 181) Bassler and Kellett (1934, pp. 429, 430).

Description : Smooth subovate to subcircular carapace with straight dorsal margin. Cardinal angles obtuse anterior greater than posterior cardinal. Anterior, posterior and ventral margins evenly rounded, though in some specimens ventral margin can be longer, giving elongate outline. Cardinal angles flattened and flattening can be traced down anterior and posterior margins until it totally fades. Maximum length at mid-height, anterior of mid-length. Maximum width posterior of mid-length, giving slightly offset elliptical dorsal view. Hinge not channelled and almost 25% shorter than maximum length. Right valve has very narrow dorsal over-reach and left valve overlaps the right around free margins.

Dimensions :

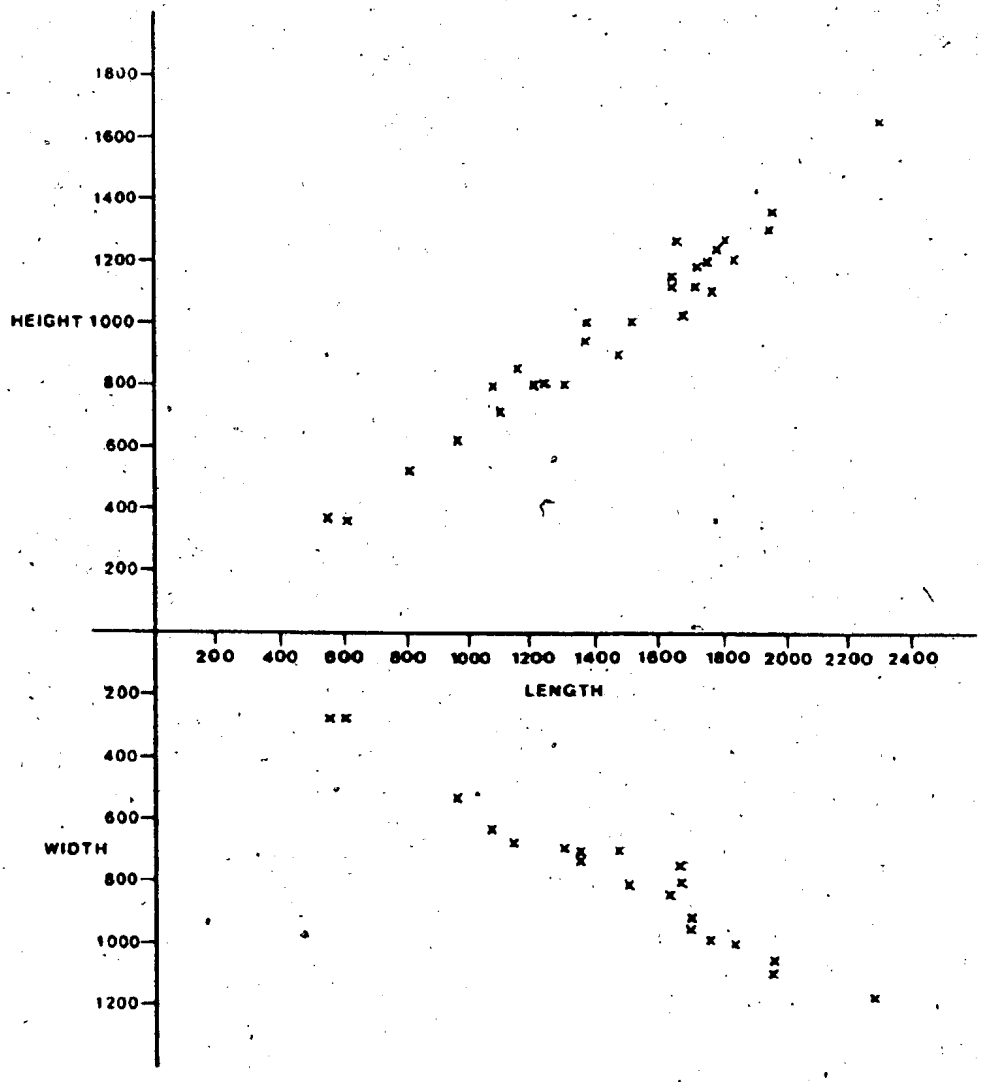
L	H	W		
1625	1150	825	Pl. 15	figs. 1, 2

Locality : Ag. 1, Ag. 2, Ag. 4, Ag. 5, Ag. Bk. 2, Ag. Bk. 3, Mi. 1, Wo. 6

Occurrence: Southwestern Newfoundland, Ireland, U.K.

Remarks : In the scattergram (Text-fig. 6.24) no discrete instar groupings can be seen due to the lack of specimens. The species never occurs abundantly in collections, and, since it is most abundant in the upper Tournaisian (Robinson, 1978), this record represents one of the later occurrences of the species.

Chamishaella kaisini Rome is referred to



Text-fig. 6.24 : Growth sequence for *Shemonaella scotoburdigalensis* from Assemblage II.

Shemonaella because it has no dorsal over-reach (Coen, pers. comm, 1982). Coen (1982, p. 287) described *Shemonaella* sp. as being distinct from *Shemonaella* sp. 66 by virtue of its more outline, however, the species is not illustrated by Coen and therefore a comparison cannot be made without recourse to the type material.

Genus *Chamishaella* Sohn, 1971

Diagnosis : Paraparchitaceans lacking spines and an incised dorsum. Over-reach of one valve above the hinge-line, dorsal margin straight to gently convex.

Type-species : *Chamishaella brosgei* Sohn, 1971.

Stratigraphic range : Tournaisian, Visean, (?lower Namurian)

Chamishaella suborbiculata (Munster, 1830)

Pl. 18, figs. 1 - 7, Pl. 19 figs. 1 - 3

Material : Several thousand specimens, being about 70% of the total ostracode collection.

Synonymy : 1830 *Cythere suborbiculata* Munster, p. 65.

1865 *Leperditia suborbiculata* (Munster) Jones and Kirkby, p. 407, Pl. 20, figs. 7a - c.

1896 *Leperditia suborbiculata* (Munster) Jones and Kirkby, p. 180, Pl. 11, fig. 11.

1929 *Paraparchites gibbus* Bell, p. 185, Pl. 34, figs. 6, 6a,b.

1939 *Paraparchites suborbiculatus* (Munster) Kummerow, p. 13, Pl. 1, figs. 6a - c.

1951 *Paraparchites suborbiculatus* (Munster) Posner, p. 22, Pl. 1, figs. 2 - 5.

1966 *Paraparchites suborbiculatus* (Munster) Gorak, p. 99, Pl. 46, fig. 5.

1967 *Paraparchites suborbiculatus* (Munster) Gorak, p. 45, Pl. 25, figs. 1, 2.

1968 *Paraparchites suborbiculatus* (Munster) Bushmina, p. 27, Pl. 1, fig. 2.

1970 *Paraparchites suborbiculatus* (Munster) Bushmina, p. 7, Pl. 2, fig. 1.

Description : Smooth, subovate carapace with straight to very slightly convex dorsal margin. Ventral border evenly rounded and slightly oblique anteriorly. Cardinal angles obtuse, anterior angle being marginally the greater. Anterior margin broader than posterior, however, ventral swing only slight and becomes less obvious with successive instars. Left valve overlaps right around free margins. Right valve has minor over-reach of dorsal border, hinge about 3/4 maximum length. Maximum length above mid-height, maximum height just anterior of mid-length. Maximum width posterior of mid-length, giving tumid ellipsoidal outline in dorsal aspect. Steinkerns indicate a broad inner lamella is present. Specimens have been found with gaping valves (Pl. 19, fig. 2), and also with valves opened but apparently still attached at hinge-line (Pl. 19, fig. 1) (cf. Coquel et al., 1976, p. 81, Pl. 1).

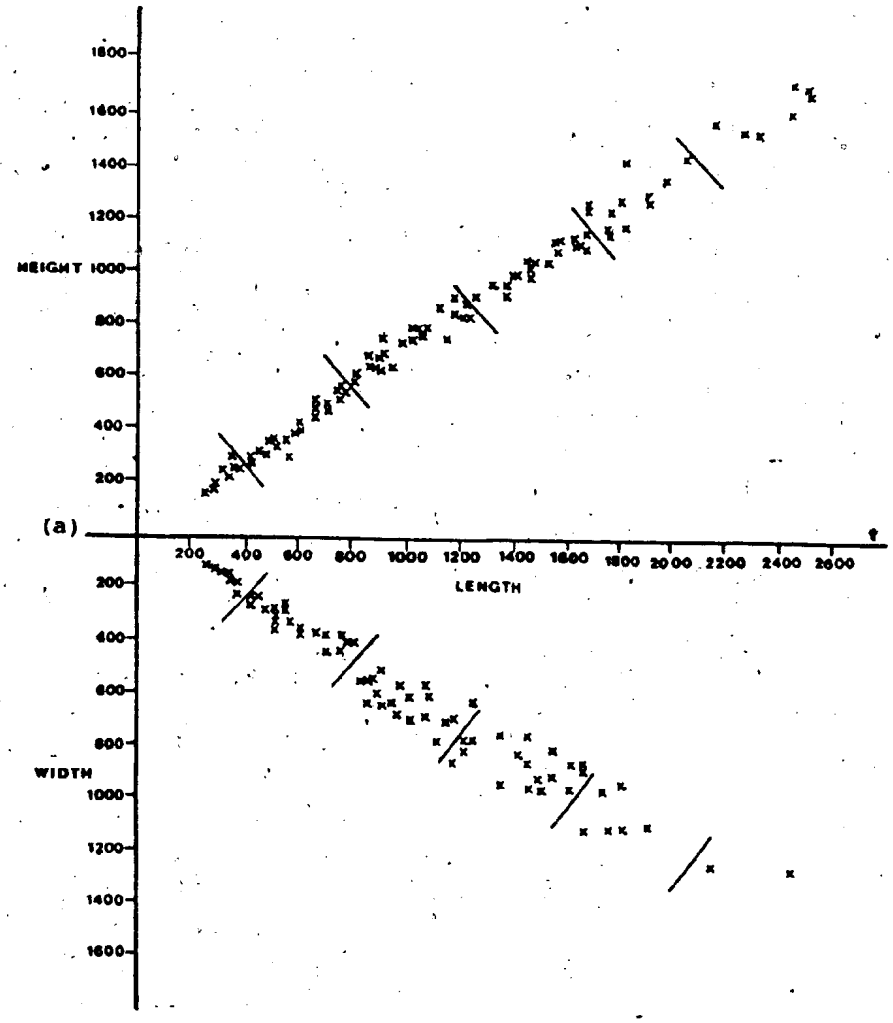
Dimensions :

L	H	W		
1325	975	900	Pl. 18	figs. 1 - 5
1250	800	875	Pl. 19	fig. 2
1225	980	800	Pl. 19	fig. 3
975	725	-	Pl. 19	fig. 1
625	425	375	Pl. 18	figs. 6, 7

Locality : Ag. 1, Ag. 2, Ag. 3, Ag. 4, Ag. 5, Ag. 6, Ag. Qu. 1
Ag. Bk. 2, Ag. Bk. 3, B. 1, B. 2, B. 3, B. 4, B. 5, B. 7
Mi. 1, Bk. 1, CR. Nodo. 3, CR. Nodo. 4
SC, Nodo. 3, SC. Nodo. 4, SC. Nodo 6, SC. Nodo. 8,
SC. Nodo. 9, CC. 6, CC. 7, CC. 8, CC. 9, SC. Jeff. 2
Wo. 2, Wo. 4, Wo. 5, Wo. 6, Wo. 9, Wo. 10, Wo. 12,
Crabb. 2-5, Jeff. 1-2, NS. 3, NS. 4, NS. 5, NS. 6

Occurrence: Hants and Antigonish Counties, Nova Scotia; southwestern Newfoundland; Ireland; U.K.; Germany; Russia.

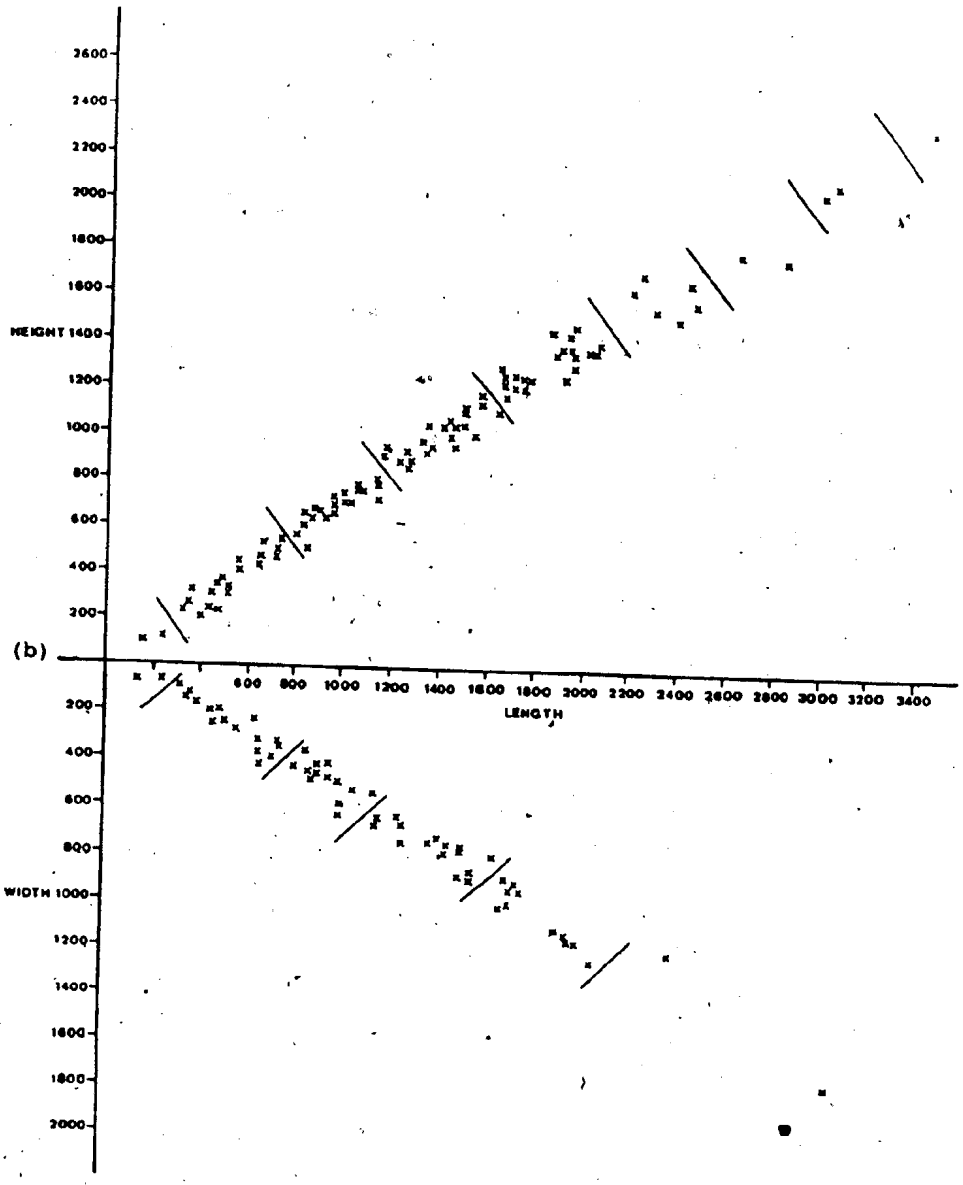
Remarks : For a discussion of the growth sequences exhibited by this species see section 4.10.3. *Chamishaella suborbiculata* differs from *Chamishaella tumida* Kummerow, 1939, by virtue of the dorsal hump (umbonate over-reach) on the right valve of the latter (Kummerow, 1939, p. 22). This form is more tumid in dorsal view and the posterior aspect is much more oval than is typical for *Chamishaella brosgei* Sohn, 1971. *Leperditia okeni* was first figured by Jones and Kirkby (1865, p. 406, Pl. 20, figs. 1 - 3) however, many subsequent reports assigned to this species are erroneous, both at the generic and specific level (Sohn, 1971, p. 17). *C. suborbiculata* is more tumid, and lacks the obliquity and pronounced truncation of the ventral margin that is typical for *Chamishaella okeni*.



Text-fig. 6.25 : Growth sequences for *Chamishaella suborbiculata*

from a : Assemblage II

b : Assemblage III


HEIGHT
WIDTH
LENGTH
(b)

Chamishaella n. sp. A.

Pl. 20 figs. 1 - 6

Text-fig. 6.26

Material : 173 specimens, mostly steinkerns and exfoliated carapaces.

Diagnosis : Differs from all other species referred to genus by virtue of inflated ventral part of valves resulting in overhang and incised ventral margin. Very narrow right over left dorsal overlap.

Description : Carapace smooth, large subovate in outline. Dorsum flattened and left valve over-reaches right around free margins. Right valve over-reaches left along dorsal region. Hinge straight and about 3/4 total length. Obtuse cardinal angles often rounded. Anterior border is more broadly rounded than posterior. Maximum length inclined from point of maximum curvature for posterior region to that of anterior region. Maximum height at or just in front of mid-line, maximum width in juveniles at mid-line, but in larger specimens swelling is greatest posteriorly which indicates dimorphic character of heteromorph. Ventrum deeply incised with valves overhanging ventral margin, resulting in inverted heart-shaped view in posterior aspect. Undefined sub-central adductor muscle scar field is noted on some specimens. Single valves show wider duplicature anteriorly than posteriorly.

Dimensions :

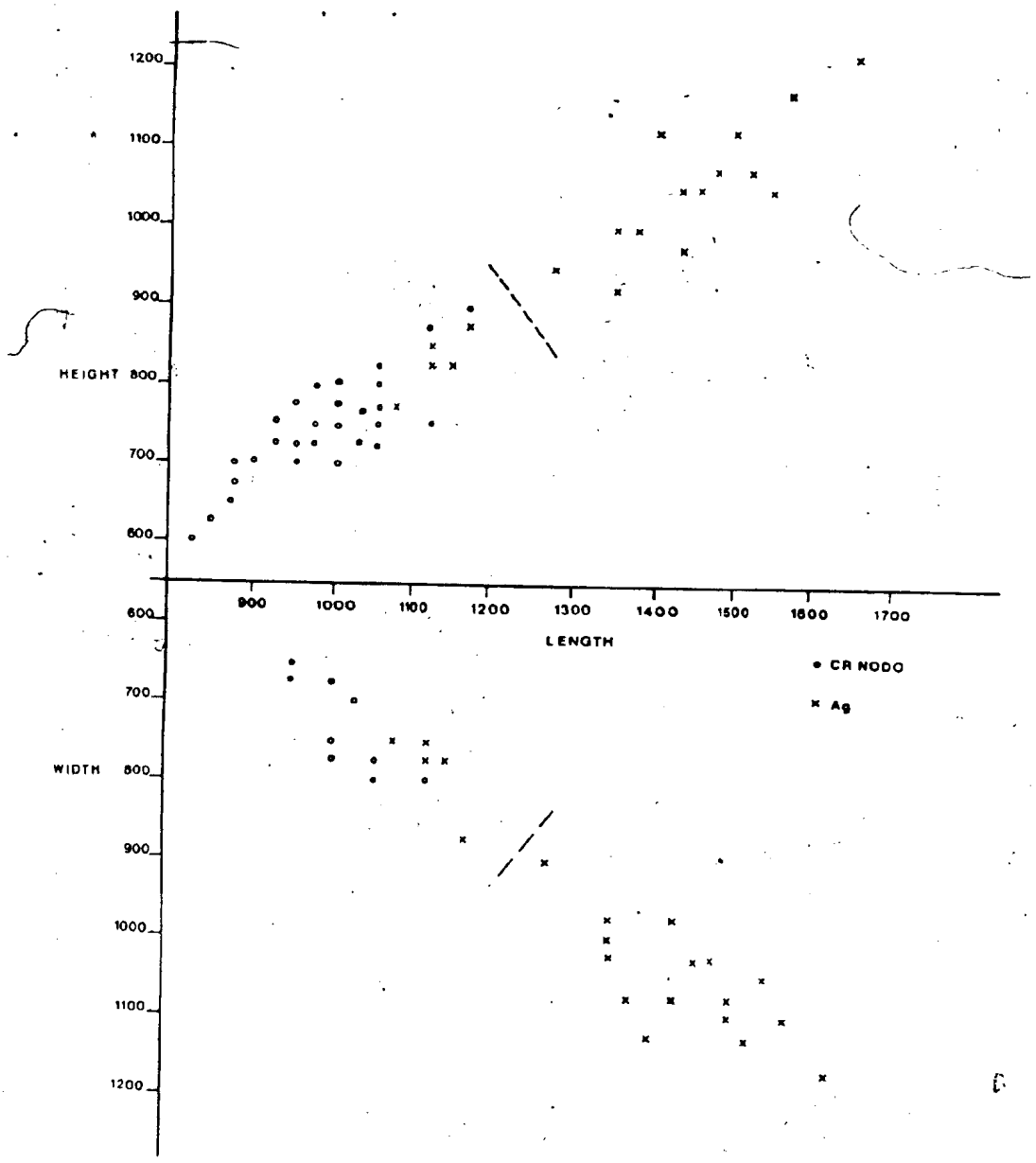
L	H	W	
1425	975	1000	Pl. 20 figs. 4, 5
1325	1000	1025	Pl. 20 fig. 6
1000	750	600	Pl. 20 figs. 2, 3
950	725	-	Pl. 20 fig. 1

Locality : Ag. 2, Ag. 4, Ag. 5, Ag. Qu. 1, B. 1, CR. Nodq. 4, Wo. 5

Occurrence Southwestern Newfoundland.

Remarks : This species does not show a complete instar sequence (Text-fig. 6.26), and no fully mature specimens have been recovered. The presence of smaller specimens with an inflated venter refutes the statement of Sohn (1971, p. 13) that the ventral tumidity may be a heteromorphic character not diagnostic of a new species. In keeping with other species of *Chamishaella* it appears that the posterior swelling is the heteromorphic character and that precocious sexual maturity may be occurring. This specimen is very similar to *Chamishaella* sp. Sohn (1971, Pl. 5, figs, 27 - 31), however the "horizontal pleat along the dorsal margin of the left valve" is not as well defined, though this may be a function of preservation. Other similar specimens described in the literature include *Paraparchites inflatus* (Munster) Kummerow (1939, p. 14, Pl. 1, figs. 9, 10) *Paraparchites galbus* Posner (1951, pp. 25, 26, Pl. 2. fig. 1) *Paraparchites ukrainikus* (Tschernyshev) Gorak (1967, pp. 49, 50, Pl. 15 fig. 5) and *Leperditia bosquetina* Jones and Kirkby (1886, p. 254, Pl. 7, fig. 2) .

The age range of these specimens is Meramecian (Sohn, 1971), C_2 and S, Visean (Kummerow, 1939), C, (Gorak, 1967), lower Carboniferous (Posner, 1951) and Carboniferous Limestone Series (Jones and Kirkby, 1865, 1886), which might indicate that a total range may be lower to upper Visean.



Text-fig. 6.26 : Growth sequence for *Chamishaella* n. sp. A.

from Assemblages II(Ag.) and V(CR. Nodo.).

Genus *Shivaella* Sohn

Diagnosis Paraparchitaceans with 2 dorso-posterior spines, one on each valve.

Type-species : *Shivaella sumetia* Sohn.

Stratigraphic range : Carboniferous.

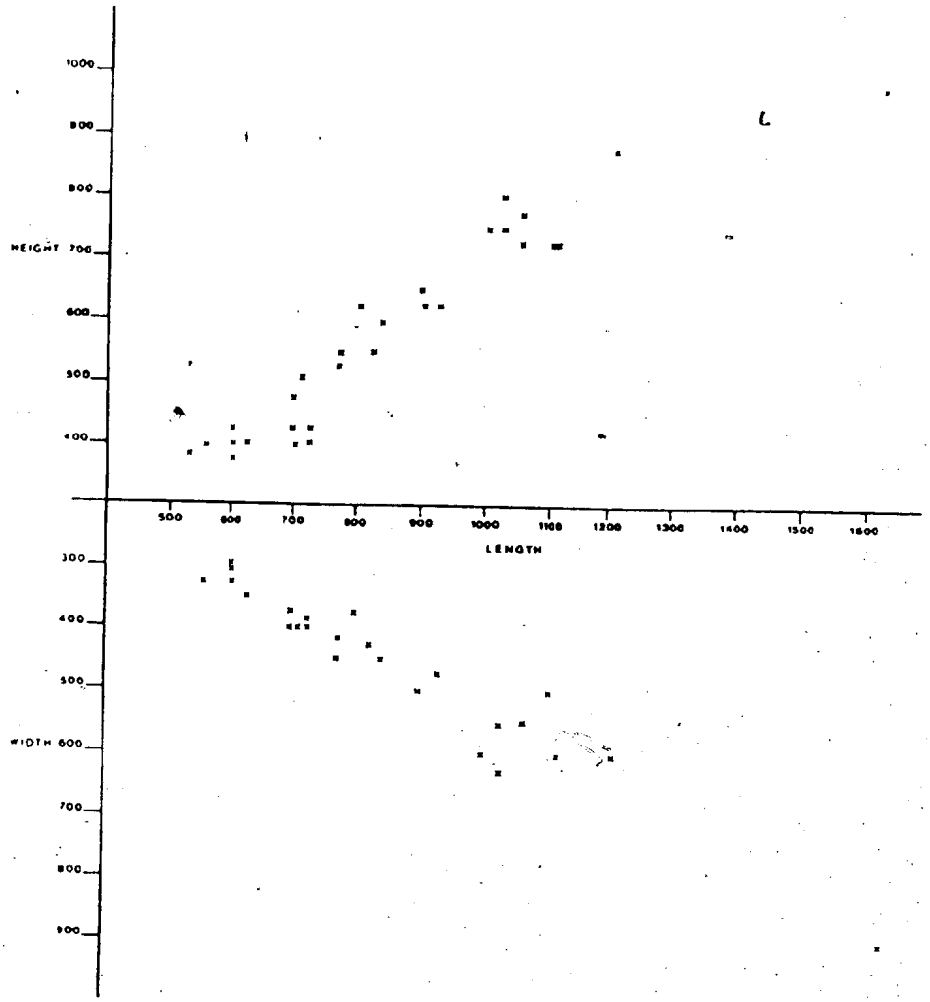
Shivaella sp.

Pl. 19 figs. 4 - 7

Text-fig. 6.27

Material : 33 carapaces, steinkerns and valves.

Description : Smooth, subovate carapace with straight dorsal margin. Cardinal angles about 120 , posterior being less than anterior. Anterior margin more broadly rounded than posterior. Strong ventral swing more pronounced in early instars than in later ones. Maximum height at or in fromt of mid-length Maximum width central in instars. Carapace ellipsoid in dorsal outline, in posterior view it is compressed ellipsoidal with very slight ventral overlap and narrow venter. Maximum length inclined from posterior cardinal angle to point of maximum curvature on anterior margin. Hinge about 2/3 maximum length slightly incised. Left valve narrowly overlaps right around free margins. Posterio-dorsal corner of each valve has spine situated closer to dorsal margin than posterior. Spines not always equidistant and where this occurs right spine situated slightly forward of left. Most specimens are steinkerns and spines are not always complete, but it is evident that they were hollow. Spines perpendicular to dorsal



Text-fig. 6.27 : Growth sequence for *Shivaella* sp. from Sub-assemblage IIB.

margin and obliquely inclined to carapace. Bases of the spines often equal in diameter to length. Inner lamella observed on steinkern material in form of grooves around free margins.

Dimensions :

L	H	W		
710	525	400	Pl. 19	fig. 6
600	375	325	Pl. 19	fig. 5
550	400	325	Pl. 19	fig. 4

Localities : B. 1, B. 4, Ag. 1, Ag. 6.

Occurrence: Port au Port Peninsula, western Newfoundland.

Remarks : At least three instar groups are present (Text-fig. 6.27) though there are no adults. The species described is distinctive in that the spines are closer to the dorsal margin than they are to the posterior, and the maximum height is anterior to the mid-line. The ventral margin is not incised. Sohn (1971, P. 10) suggested that the incised venter might be a feature diagnostic of Mississippian representatives of the genus. A survey of the literature would tend to suggest that this is likely. *Shivaella* is present in Fammenian strata (Becker and Bless, 1974, Pl. 15) and ranges through the Carboniferous, it is however not usually as common as other members of the Paraparchitacea with which it occurs. The first appearence of *Shivaella* in the lower Carboniferous of Western Europe is that of *Shivaella* sp. cf. *Shivaella armstrongiana*, Becker and Bless (1974, p. 29), which occurs in the lower Tournaisian of the Cornwall-Rhenish Basin. *S. armstrongiana* is described from the Viséan of the basins north of the Wales-Brabant Massif (Jones and Kirkby, 1886c, p. 253;

Latham, 1933, p. 356; Bless et al., 1981, p. 146). In Russia the same species is reported from the lower and upper Tournaisian of the Russian Platform (Tschigova, 1967, pp. 7, 37, 66, 119, 131), Donetz Basin and Kolmyan Massif (Bushmina, 1975, p. 33) and the Tulsky-Alexinsky horizons of the Pod Moscow Basin (Posner, 1951, p. 24; Zanina, 1956, p. 192). Other *Shivaella* species are reported from the Dinantian, including *Shivaella longa* of the Donetz Basin (Tschigova, 1967, p. 213), *Shivaella quasiporrectus* from the Kusznetsk Basin (Bushmina, 1968, p. 30) and the River Lena (Bushmina 1970, pp. 6, 7) and *Shivaella ventricosus* (Tschigova) *sensu* Bushmina (1970, p. 10, Pl. 11, fig. 4) as well as *Shivaella carbonaria* from the Donetz Basin (Gorak, 1967, p. 46). *Shivaella* is also reported from the Dinantian of Poland (Kummerow, 1953, p. 11; Olempska, 1981, pp. 47, 48). *Shivaella macallisteri* (Blumenstengel, 1975, p. 758), should not be taken as being a definite *Shivaella* since it is described only from right valves. None of these species appear to possess an incised venter.

In North America, *Shivaella pingue* from the Kinderhookian of Alberta (Green, 1963, p. 126) *Shivaella mertei* and *Shivaella suppetia* from the Meramecian of Alaska (Sohn, 1971, pp. 9, 10) posses an incised venter. Forms including *Shivaella macallisteri* from the Kinderhookian to Osagean of California (Sohn, 1972, p. 5) and *Shivaella nickelsi* from the Chesterian of the Mid-Continent (Ulrich, 1891, p. 200; Harlton, 1929, p. 255) do not show incised venters. The only unquestioned Pennsylvanian species are *Shivaella magnus* from Kansas, (Kellett, 1933, pp. 65, 66), *Shivaella brazoensis* from Texas, (Coryell and

Sample, 1932, pp. 243, 249, 250) and *Shivaella* sp. (Sohn, 1977, Pl. 1, figs. 6 - 8) from Arkansas, all of which lack incised venters. It is therefore probable that species of *Shivaella* which developed incised venters are restricted to the Mississippian faunas of North America only.

Genus *Shishaella* Sohn, 1971

Diagnosis : Paraparchitaceans with only one dorsoposterior spine situated on right valve.

Type-species : *Paraparchites nickelsi* var. *cyclopea* Girty, 1910, Sohn, 1969.

Stratigraphic range : Lower Mississippian to lower Permian.

Shishaella moreyi Sohn, 1975

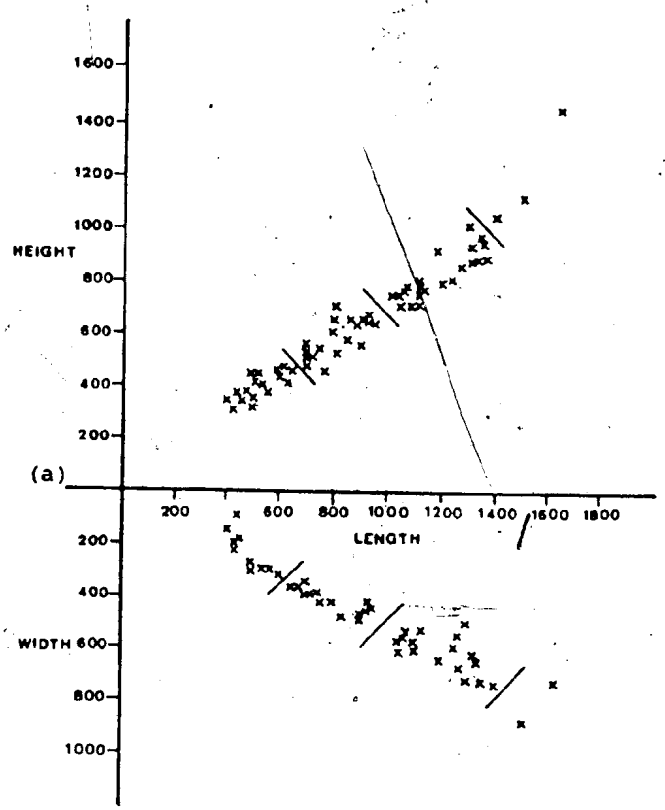
Pl. 21 figs. 1 - 7, Pl. 22 figs. 1 - 3

Text-fig. 6.28

Material About 950 steinkerns and exfoliated carapaces.

Synonymy : 1975 *Shishaella moreyi* Sohn, p. 12, Pl. 3, figs. 1 - 15.
1935 *Paraparchites nickelsi* Morey, p. 474, Pl. 54, fig. 8.
?1939 *Leperditia juvensis* Croneis and Gale, p. 255, Pl. 5, fig. 20.
?1968 *Paraparchites* sp. cf. *P. nickelsi* (Ulrich) Jones, p. 44, Pl. 5, figs. 3, 4a,b.

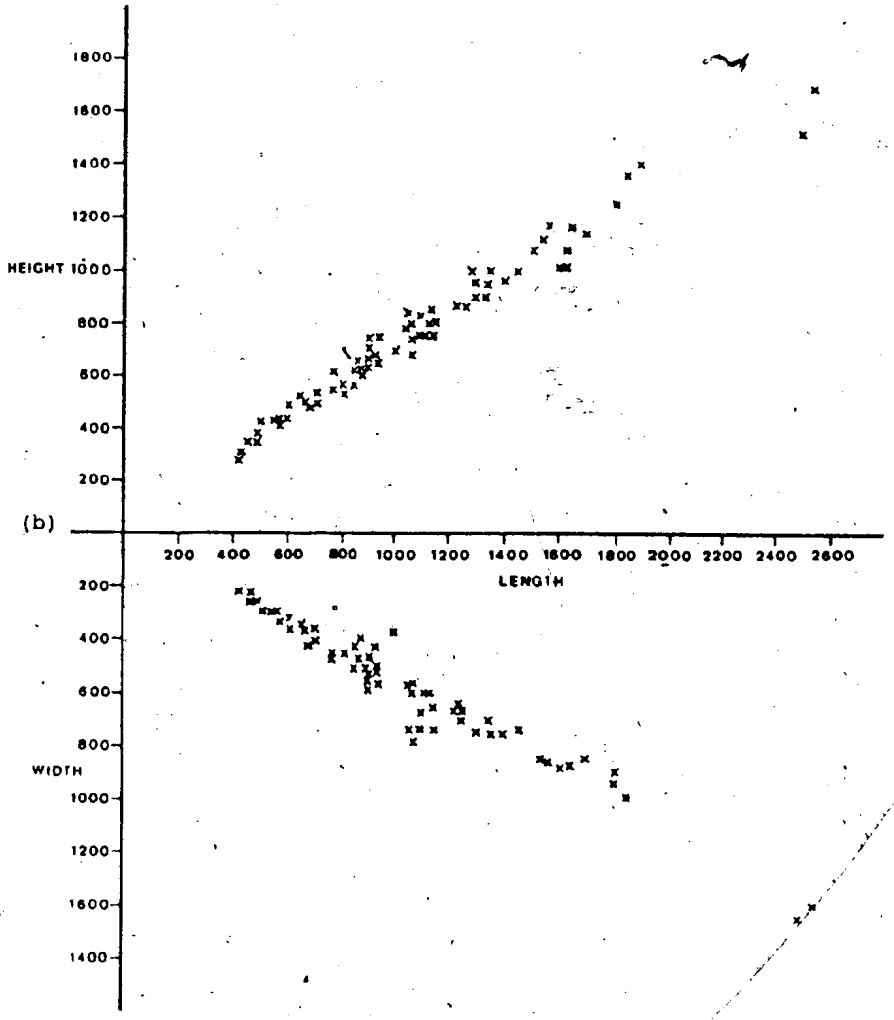
Description : Smooth sub-circular carapace with straight dorsal margin and obtuse cardinal angles. Anterior angle more obtuse then posterior. Anterior margin slightly more broadly rounded than posterior. Posterior margin has pronounced antero-ventral swing in early instars, becoming less obvious in later instars.



Text-fig. 6.28 : Growth sequences of *Shishaella moreyi* from

a : Sub-assemblage IIB

b : Assemblage III


HEIGHT
1800
1600
1400
1200
1000
800
600
400
200
(b)
200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600
LENGTH
WIDTH
200
400
600
800
1000
1200
1600
1400

Maximum height anterior of mid-length, maximum width at, or about, mid-height and mid-length. Hinge about 3/4 maximum length. Right valve has noticeable over-reach of dorsal margin, left valve overlaps right around free margins. Inner lamella seen on steinkern material. Spine developed on postero-dorsal corner of right valve Spine situated about 1.5 diameters of base of spine from both cardinal angle and dorsal margin and twice that distance from posterior margin. Spine can be long or short or small tubercle; size of spine probably being related to state of preservation. Exact position of spine variable, but is probably a function of, individual variations and not of specific significance. At posterior cardinal angle is pinched-flattened area which fades rapidly as it passes down posterior margin. Feature not seen on junior instars.

Dimensions :

L	H	W		
1750	1175	900	Pl. 22	figs. 1 - 3
1100	700	575	Pl. 21	figs. 1 - 3
725	525	400	Pl. 21	figs. 4 - 7

Locality : B. 1, B. 2, B. 3, B. 4, B. 5, B. 7, Ag. Bk. 2, Ag. Bk. 3 Ag. 1, Ag. 2, Ag. 3, Ag. 4, Ag. 5, Ag. 6, Ag. Qu. 1. NS. 4

Occurrence: Port au Port Peninsula, western Newfoundland; Hants County, Nova Scotia; Wyoming and Illinois, U.S.A.; Australia.

Remarks : In the scattergram (Text-fig. 6.28) poorly defined instars are seen, though fully mature adults are apparently scarse. This species is similar to *Shishaella williamsae* Sohn (1971, p. 15, Pl. 8, figs. 1 - 5, 11 - 25, 31 - 44) in the position

of the spine, however, the flattened posterior corner and the ventral swing are diagnostic of this material. The material from the Maritimes may be conspecific with *Shishaella harltoni* (Bradfield), described from the Pennsylvanian of Oklahoma (Bradfield, 1935, p. 33, Pl. 1, fig. 9). However, the spine on *S. harltoni* appears to be further removed from the posterior margin than is typical for the Maritime material. *Shishaella moreyi* differs from *Shishaella* cf. *S. williamsae* Sohn (1971, p. 16, Pl. 8, figs. 6 - 10, 26 - 30) because the former is more sub-circular and the ventral margin is less convex. *Shishaella porrecta* Zanina (1956, p. 192, Pl. 1, figs. 1a,b) differs from *S. moreyi* by virtue of the sub-circular outline, the more equal cardinal angles and the position of the spine. *Shishaella* aff. *S. porrecta* Zanina *sensu* Becker and Bless is a form that has been reported several times from Europe (Becker and Bless, 1974; Bless et al., 1974; Bless et al., 1981; Coen, 1982) and also as *Shishaella nana* Rome, 1977. Coen (1982, p. 287), on the basis of steinkern material, suggests that *S. nana* is junior synonym of *S. porrecta*. By comparing the ventral swing of the carapace as well as the postero-cardinal flattening drawings of the holotype of *S. nana* (Coen, pers. comm., 1982) would suggest that it is indeed conspecific with *S.* aff. *S. porrecta*. The main difference between this species and *S. moreyi* is the position of the spine, which appears to be further from the posterior margin than in any of the other discussed species. It is possible that there exists a spectrum of species that is variable with respect to the degree of ventral swing and position of the spine in relation to

the posterior margin. *S. williamsae* Sohn, 1971, would be one end of this spectrum and *Shishaella* sp. aff. *S. porrecta* Zanina *sensu* Becker and Bless, 1974, would be the other end. A form with the characteristics of *S. moreyi* Sohn, 1975, would be almost mid-distant between these two extremes. If this is indeed the case it probably explains the individual variations of the spine position and also the greater ventral swing that is seen in my specimens.

Suborder Indet.

gen. et sp. indet. 3

Pl. 22 figs. 4 - 7

Material : About one dozen steinkerns.

Description : Carapace small elongate, with equally rounded posterior and anterior margins. Form of the carapace rectangular in all aspects, sides are parallel and steep. Dorsal margin straight, sub-parallel to ventral. Cardinal angles indistinct. Maximum length at mid-height and maximum height at anterior cardinal angle. Maximum width central, but equal along main body of carapace. Ends of carapace, in dorsal aspect, are extended beyond rectangular body of the shell and rounded. Posterior and anterior margins depressed, anterior being more so than posterior. Hinge stepped anteriorly and sinuous. Right valve overlaps left slightly around free margins. Calcified inner lamella appears as thin longitudinal depression that runs along either side of mid-ventral line.

Dimensions :

L	H	W	
480	275	200	Pl. 22 figs. 4, 5
460	250	200	Pl. 22 figs. 6, 7

Localities : Ag. 2, Ag. 5

Occurrence: Port au Port Peninsula, western Newfoundland.

Remarks : The inner lamella and marginal areas suggest that the form is not related to the *Youngiella* or *Moorites*. The dorsal outline and hinge sway is reminiscent of the genus *Bairdiolites*, however, the lateral outline is not. Lethiers (1981, p. 88, Pl. 19, figs. 183 - 185) described material with similar characteristics in the genus *Bairdiocypris* however there does not appear to be sufficient evidence for the assignment. The designation of this species remains enigmatic.

Order MYODOCOPIDA Sars, 1866

nom. correct. Pokorny, 1953 pro Myocopa Sars, 1866

Suborder CLADOCOPINA Sars, 1866

nom. correct. Sylvester-Bradley in Moore, 1961 pro Cladicipa Sars, 1866.

Family POLYCOPIDAE Sars, 1866

Diagnosis : See Sars, 1928, p. 29.

Genus *Polycope* Sars, 1866

Diagnosis : See Sars, 1929, pp. 29, 30.

Type-species : *Polycope orbicularis* Sars, 1866

Stratigraphic range : (?Devonian) lower Carboniferous to Recent.

Polycope n. sp. A.

Pl. 23 figs. 1 - 4

Material : About 150 steinkerns and exfoliated specimens.

Diagnosis : Differs from previously described species of *Polycope* Sars 1866 from Carboniferous by smooth carapace and presence of antero-marginal spines.

Description : Very small, smooth, sub-circular carapace, possessing short straight hinge, with edges of valves rising above hinge furrow to give rounded dorsal margin. Carapace equivalved compressed ellipsoidal in posterior aspect. Cardinal angles poorly defined and orbicularity of carapace only broken by antero-ventral slope. No indication of a valve gape or anterior antennal notch. Anterior margin marked by angular truncation of circular outline angled into the ventral margin. Anterior margin of each valve supports at least one spine situated at edge of what is probably marginal rim. Apparent difference in spine direction is attributed to position at which spine is broken, in longest spine curvature of spine is obliquely antero-ventral. Shell is thin but in some cases has been thickened by calcite growth. Sub-central muscle-scar field often seen and in one specimen appears to be formed by a poorly defined rosette of about 5 scars arranged in two rows. Muscle scars are best seen in steinkern material.

Dimensions :

L	H	W		
225	220	100	Pl. 23	fig. 1
180	175	75	Pl. 23	fig. 2
175	175	75	Pl. 23	figs. 3, 4

Locality : B. 1, B. 7, Ag. 2, Ag. 5, Ag. Qu. 1, SC. Nodo. 3 NS. 3, NS. 4

Occurrence: Port au Port Peninsula, western Newfoundland; Hants and Antigonish Counties, Nova Scotia.

Remarks : References of Carboniferous Polycopidae are few and most of them lack formal descriptions or illustrations (Armstrong, 1876, p. 45; Jones, 1873, p. 412; Jones and Kirkby, 1867, p. 223, 1886a, pp. 496, 503, 509, 1886e, p. 501; Young, 1891, p. 306). The first illustrated specimens of *Polycope* form the Carboniferous were described by Jones, Kirkby and Brady (1874) as *Polycope burrovii* (p. 54, Pl. 2, figs. 2a - c) *Polycope simplex* (pp. 54, 55, Pl. 2, figs. 1a - c, 10, 12, Pl. 5, figs. 1a - d) and *Polycope youngiana* (p. 56, Pl. 5, figs. 2a - f) There are questioned referrals to *Polycope* by Kummerow (1939, p. 63, Pl. 7, fig. 10) from the Tournaisian of Germany and also by Blumenstengel (1969, p. 22, Pl. 2, figs. 20 - 23) from the Devonian of Germany. Jones (1881. p. 340, Pl. 9, fig. 4) describes *Polycope devonica*, which is possibly the earliest unquestioned polycopid. None of these references describe the muscle scar in detail, however, the illustrations of *Polycope* spp. in Sars (1928, Pl. XV, fig. 2, Pl. XVI figs. 1, 2, Pl. XVII, figs. 1, 2) indicate that a muscle attachment area consisting of three discrete muscle spots is diagnostic. The material of this collection shows that five muscle spots is not uncommon, of which three are much more

prominent than the other two. Despite the lack of any non-exfoliated spine-bearing specimens, it is possible to build a composite of the form of this species, which is the only description of the genus in the Carboniferous outside of Western Europe.

The major problem is that many of the specimens are steinkerns and lack the detailed morphology necessary to categorically place them all together in the same species, however further sampling of better material would be an aid in the understanding of the detailed palaeoecology and stratigraphy of this species.

Class MALACOSTRACA Latrielle, 1802

Subclass EUMALACOSTRACA Grobben, 1892

Superorder PERACARIDA Calman, 1904

Diagnosis : See Hessler in Moore, 1969, pp. 360 - 363

Order MYSIDACEA Boas, 1883

Diagnosis : See Hessler in Moore, 1969, pp. 363 - 365.

Suborder PYGOCEPHALOMORPHA Beurlen, 1930

Diagnosis : See Schram, 1974, p. 11.

Remarks : The similarity of pygocephalomorphs to the modern representatives of the Mysidacea was suggested by (Woodward, 1907: Peach, 1908). However, based upon the nature of the thoracic protopod and tail fan, Brooks (1962), considered that the

Palaeozoic caridoid eumalacostracans could be better defined as a distinct entity, the superorder Eocarida. Schram (1974) questioned this subdivision, re-established the pygocephalomorphs within the Mysidacea and finally (Schram, 1981b) restricted the Eocarida to "palaeozoic families for which no adequate data exists on the nature of carapace thoracopods and possible brood pouch." The reassignment of the pygocephalomorphs to the msyidacean peracarids was based primarily upon the presence of oostegites, carapace morphology and thoracic exopods (Schram, 1974).

Since the material of this collection consists only of cephalothoracic shields the classification of the Pygocephalomorpha cannot be discussed in detail, however the classification used herein follows that of Schram (1974, 1979) since it stresses the similarity of Palaeozoic pygocephalomorphs and the recent mysidaceans.

Family PYGOCEPHALIDAE Brooks, 1962

Diagnosis : See Brooks, 1969, p344.

Type-genus : *Pygocephalus* Huxley, 1857.

Stratigraphic range : Lower and upper Carboniferous.

Genus *Bellocaris* Fong, 1972.

Diagnosis : See Fong, 1972, p. 595

Stratigraphic range : Mississippian.

Bellocaris newfoundlandensis Fong, 1972

Pl. 25 figs. 1 - 3

Text-fig. 6.30

Material : About 50 specimens.

Synonymy : 1972 *Bellocaris newfoundlandensis* Fong, p. 594, Text-figs. 2 - 4.

1978 *Bellocaris newfoundlandensis* Fong, Schram et al., p. 1384, fig. 5.

1982 *Bellocaris newfoundlandensis* Dewey and Fahraeus, pp. 668, 670, Pl. 1, figs. 5 - 7.

Description : Cephalo-thoracic shield smooth, dorsally rounded, and lacks median dorsal ridge. Narrow posterior groove communicates with wide ventral groove. Ventral border characteristically upturned to form horizontal shelf. Superior lateral carina supressed as poorly defined hepatic spine, or may be totally lacking. Inferior lateral carina close to shelf and faces just in front of posterior groove. Antero-lateral and gastric spines prominent. Cervical groove well developed and parallel to shorter, anteriorly trending, rostral groove. Carapace smooth.

Dimensions : In millimetres (all lengths are taken at mid-dorsum)

	L	H	W		
GSC 69155	18.5	8.2	-	Pl. 25	fig. 1
GSC 69154	14.0	7.0	12.0	Pl. 25	fig. 3
GSC 69156	13.5	7.0	12.5	Pl. 25	fig. 2

Locality : Aguathuna "Island", GC. 1

Occurrence: Port au Port Peninsula, western Newfoundland.

Family TEALLIOCARIDIDAE Brooks, 1962

Diagnosis : See Brooks, 1962, p. 272.

Genus *Tealliocaris* Peach, 1908

Diagnosis : See Schram, 1979, p. 75

Type-species : *Anthrapalaemon woodwardi* Etheridge, 1871

Stratigraphic range : Lower Carboniferous.

Tealliocaris sp. aff. *T. loudonensis* Peach, 1908

Pl. 24 figs. 1 - 3

Text-figs. 6.29, 6.30

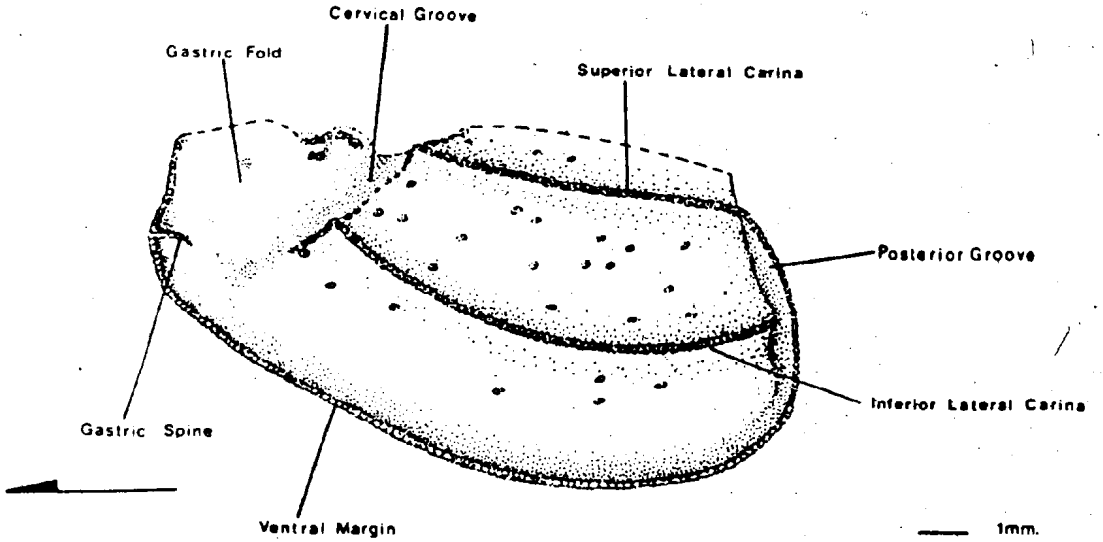
Material : About 3 dozen specimens.

Synonymy : 1982 *Tealliocaris* sp. aff. *T. loudonensis* Peach, Dewey and Fahraeus, p. 668, Pl. 1, figs. 1 - 4 Text-fig. 3.

Description : Cephalo-thoracic shield rectangular with narrow dorsal portion and no dorsal keel. Two lateral carinae meet the cervical groove. Inferior lateral carina, being most continuous, merges with groove. No prominent antero-lateral spines, dorso-anterior portion terminates in short rostrum. Posterior and ventral borders of shield are upturned to form a pronounced lip. Both lip and carinae show distinctive punctate ornament. Tuberculate ornament often present on dorsal side of superior lateral carina. Tubercles occur as row or as irregular pattern. Gastric region shows pustulose ornament. Gastric spine not continuous with gastric fold or cervical groove (Text-fig. 6.29).

Dimensions : (In millimetres)

	L	H	W	
GSC 69151	14.0	8.0	-	Pl. 24 fig. 3
GSC 69152	12.5	7.0	-	Pl. 24 fig. 1
GSC 69153	8.0	5.0	-	Pl. 24 fig. 2



Text-fig. 6. 29 : Morphology of *Tealliocaris* sp. aff. *T. loudonensis*.

Locality : B. 7 below horizon; Aguathuna "Island" - rare

Ag. Bk. 2, Ag. Bk. 3, CC. 9.

Occurrence: Western Newfoundland.

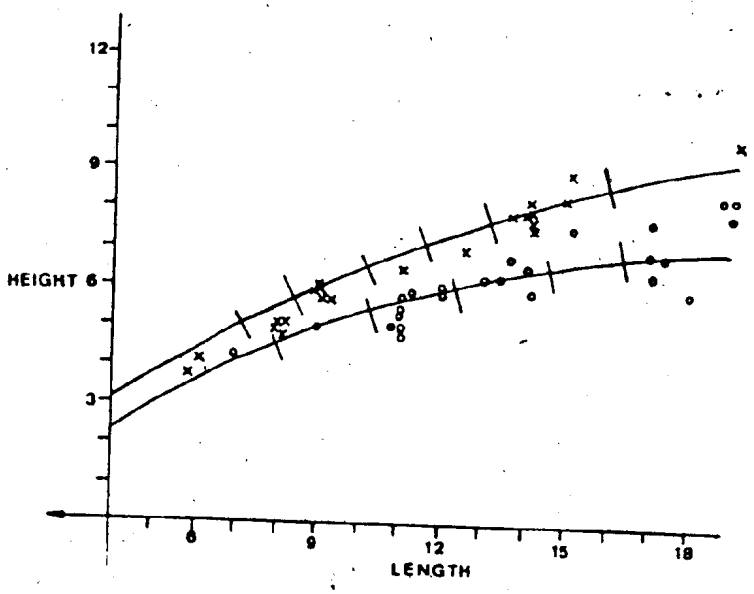
Remarks : *Tealliocaris* sp. aff. *T. loudonensis* differs from *Tealliocaris woodwardi* in the reduction of the gastric spine in the former. Schram (1979, pp. 75 - 77) synonymised *Tealliocaris loudonensis* and *T. woodwardi* and further stated (Schram, pers. comm., 1982) that he could see no consistent differences between the type material of these species. Until the type material can be investigated I propose to retain *Tealliocaris* sp. aff. *T. loudonensis*, since the reduction in the gastric spine appears to be consistent on all specimens.

Tealliocaris also differs from the three *Pseudotealliocaris* described by Copeland (1957b, pp. 44 - 47), by lacking antero-lateral spines, serrated ventral margin and dorsal keel, and by length of rostrum, inflection of gastric fold and style of ornamentation.

Tealliocaris differs from *Bellocaris* in all of the above features, except that the latter also lacks a serrated margin and dorsal keel. The main difference between the two genera is, however, the prominence of the lateral carinae in *Tealliocaris* in contrast to their virtual absence in *Bellocaris*.

Measurements of specimens of *Bellocaris newfoundlandensis* and *Tealliocaris* sp. aff. *T. loudonensis* were plotted on a length height diagram (Text-fig. 6.30). In both taxa instar groupings can be distinguished. In *B. newfoundlandensis* height appears to vary more with length than in *Tealliocaris* sp.

aff. *T. loudonensis*. For both taxa the instar groupings define curves indicative of allometric trowth (Teissier, 1961). The slopes of the two curves are significantly different. The carapace of *B. newfoundlandensis* being lower at all stages of growth than that of *Tealliocaris* sp. aff *T. loudonensis*.



Text-fig. 6.30 : Growth sequence for *Bellocaris newfoundlandensis* from Sub-assemblage IIB(o) and *Tealliocaris* sp. aff. *T. loudonensis* from Assemblage III (x).

Note : measurements in millimetres.

CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 Summary and conclusions

The study of the middle Carboniferous crustacean fauna of southwestern Newfoundland and northern and central Nova Scotia has resulted in the recognition of 34 crustacean species, 5 of which are new, and one belongs to a new genus. The ostracodes and peracarids described herein fall into seven faunal assemblages that relate to different ecological conditions. The environment with which each assemblage is associated is as follows:

Assemblage I : Nearly normal marine salinity offshore subtidal

Sub-assemblage IIA : Slightly hypersaline subtidal drowned topographic highs.

Sub-assemblage IIB : Slightly hypersaline subtidal drowned karstified coastline.

Sub-assemblage IIC : Same as IIB but represents an "event horizon".

Sub-assemblage IID : Shoreline, lateral facies equivalents of IIB.

Assemblage II subset : Biohermal fringing barrier to a hypersaline lagoon?

Assemblage III : Restricted carbonate deposition dominated lagoon with fluvial influences in lower portion and evaporitic influences in upper portion.

Assemblage IV : Raised salinity marginal marine assemblage overlain by sabkha evaporites.

Assemblage V : Restricted clastic dominated lagoon with raised and fluctuating salinities.

Assemblage VI : Raised and fluctuating salinity subtidal marginal marine environment in a regressive sequence from sub- to supra-tidal.

Assemblage VII : Raised and fluctuating salinity inter- to supra-tidal marginal marine embayments in a deltaic environment.

With the exception of Assemblage I and Sub-assemblage IIA, the assemblages are low diversity faunas, and all assemblages except Assemblage I exhibit a high dominance by paraparchitaceans. The paraparchitaceans were eurytopic opportunistic ostracodes that did not compete well with stenopotopic forms such as *Bairdia* when the environmental conditions favoured the latter. A similar relationship is noted for the peracarids *Tealliocaris* sp. aff. *T. loudonensis* and *Bellocaris newfoundlandensis*. Barriers between these species are therefore competition controlled for the eurytopes and environmentally controlled for the stenotopes. With respect to palaeocopes and kloedenellacean ostracodes, kirkbyaceans were most abundant in offshore subtidal environments, hollinomorphs in nearshore subtidal environments and kloedenellaceans and beyrichiaceans in marginal marine environments.

One of the main characteristics of most of the assemblages is that they exhibit evidence of physiological stress primarily due to the effects of raised or fluctuating salinities.

Most ostracode species recognised in this study show a reduction in size from expected values which is thought to be a function of total physiological stress and not the result of any one single environmental parameter as was previously been suggested.

It appears that stenotopic species show greater morphological variation and poor instar groupings as they approach their ecological limits, whereas the reverse would suggest yearly breeding cycles and a stable environment. Opportunistic species do not show instar groupings and it is suggested that this relates to more continuous breeding cycles. Time averaging of samples is not thought to be controlling the loss of instar groupings since different species occurring within the same environment can be shown to exhibit good and poor instar development, which would suggest different rates of reproduction. It is possible to distinguish between the lack of instar groupings in eurytopic species and stenotopic species under stress, by the low levels of morphological variability exhibited in the height/length ratio of the former.

The total crustacean fauna described in this study exhibits a high affinity to European and Russian faunas, and a low affinity to North American, Mid-Continental faunas; this is related to the oceanic circulation patterns. The lack of endemism between European and Canadian fauna is also a function of similar tectonophysical environments and climate.

7.2 Implications and further work

One of the major areas of expansion evidenced from this study relates to the need for stratigraphic continuity. It is important that a sequence of Windsorian crustaceans be described from the Maritime Basin which covers all the transgressive-regressive cycles that affected the basin. These could then be

used to develop more detailed palaeogeographic relationships and their sequential changes during the Windsorian stage. More complete stratigraphic sequences would also allow for the description of degrees of endemism at different stratigraphic intervals, evolutionary trends and ecological replacements. It would also be useful to document the development of upper Carboniferous *Carbonita* freshwater faunas. It is significant that even in the youngest samples taken from the deltaic sequences of the Woody Cape Formation (uppermost Codroy Group) no unequivocal freshwater faunas were found.

This is the first study of its kind that has provided evidence of the existence of paraparchitaceans in hypersaline conditions, and the faunal assemblages hold much potential for studying the effects of physiological stress upon crustacean faunas in terms of assemblage content, reproductive cycles and carapace variability. More detailed sampling of these environments and application of statistical tests of variability would be significantly advantageous.

More widely ranging implications revolve around the similarity of Maritime faunas to the European and Russian faunas. Firstly, it is important that a unified taxonomic data base be eatablished for European, Russian and North American Carboniferous ostracodes, especially with regard to existing type material and the proper description of many of the European species; this extends itself to the need for a new ostracode Treatise. Secondly, it is important that more studies are completed on the dispersal and migration of benthic ostracodes, so that palaeogeographic

reconstructions can be more detailed in their approach.

Application of Carboniferous ostracode studies in the Maritime Basin are primarily palaeoenvironmental. If the lower stratigraphic limits of freshwater ostracode faunas could be defined and a stratigraphic sequence containing both marine and freshwater species could be described, the palaeoecological significance of the ostracodes would be significantly enhanced.

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PLATE 1

figs. 1 - 3 *"Copelandella"* sp: figs. 1, right aspect, 0°; 1a, right aspect, 10° stereo pair fig. 2, dorsal view, fig. 3, ventral view, magnification about 130.

fig. 4 *"Copelandella"* sp: left aspect, magnification about 165.

figs. 5, 6, *Gortanella* sp: fig. 5, dorsal view magnification about 72; fig. 6 right aspect, magnification about 65.

fig. 7 *Gortanella* sp: left aspect; magnification about 60.

fig. 8 *Gortanella* sp: left aspect; magnification about 60.

fig. 9 *Gortanella* sp; left aspect; magnification about 65.

Preservation : figs. 1 - 4 are carapace material
figs. 7 - 9 are silicified material

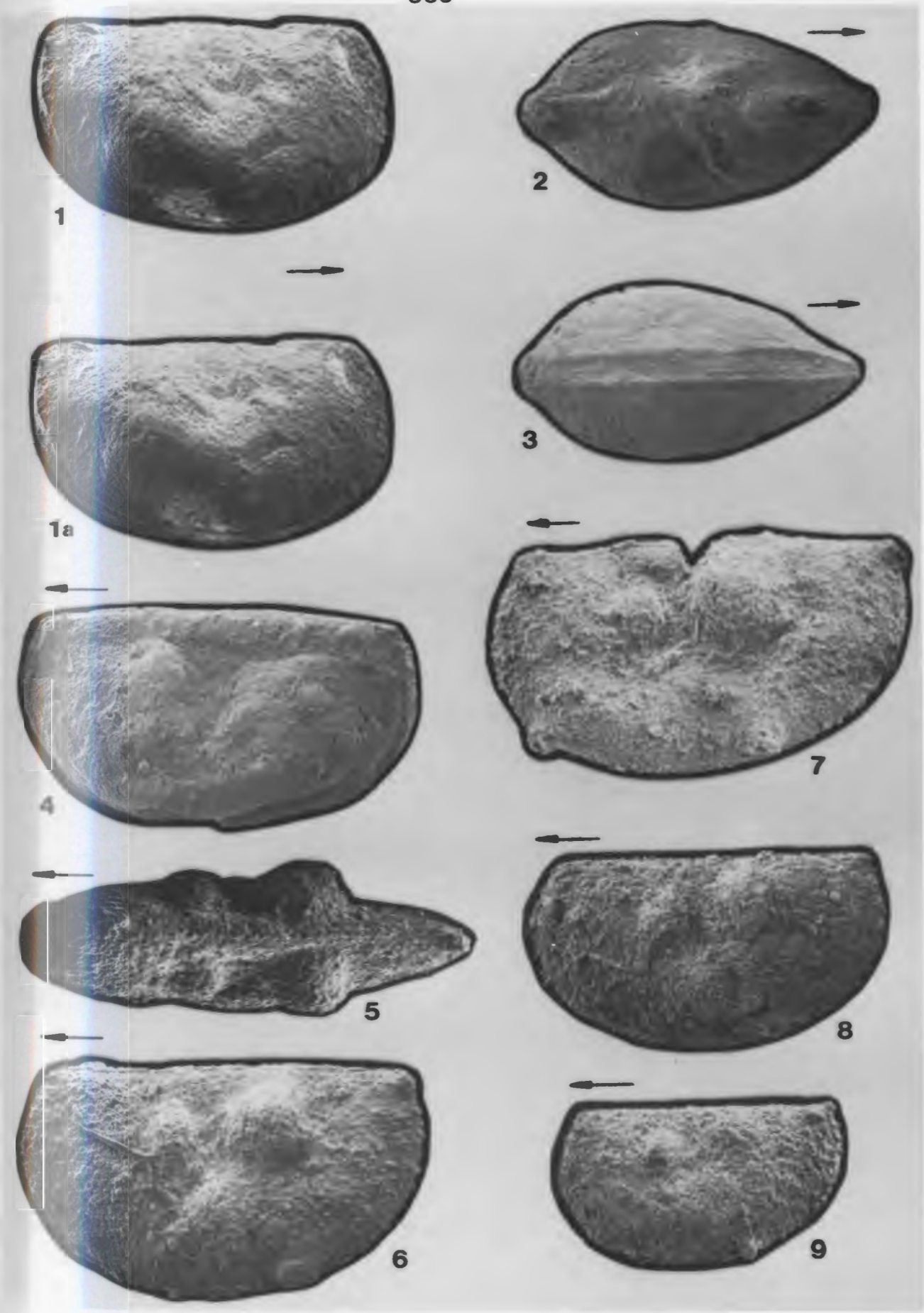
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PLATE 2

fig. 1 Genus et species novae: right oblique view, magnification about 85.

fig. 2 Genus et species novae: ventral view, magnification about 100.

figs. 3,4 Genus et species novae: fig. 3, right aspect, magnification about 65; fig. 4, enlargement of posterior region, magnification about 175.

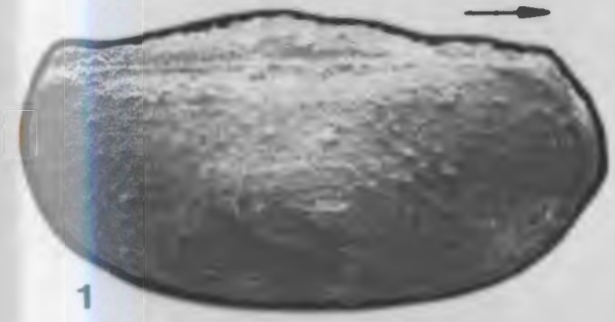
figs. 5,5a Genus et species novae: fig. 5, right aspect, 0°, fig. 5a, right aspect, 10° stereo pair, magnification about 110.

fig. 6 *Amphissites* sp. aff. *A. centronotus*: right aspect, magnification about 95

fig. 7 *Amphissites* sp. aff. *A. centronotus*: right aspect, magnification about 85

fig. 8 *Amphissites* sp. aff. *A. centronotus*: posterior view, magnification about 45

fig. 2 is probably a steinkern, all other figs. are carapace material.



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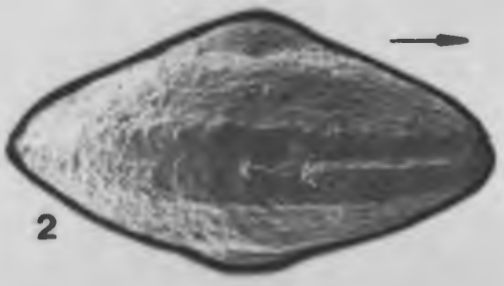

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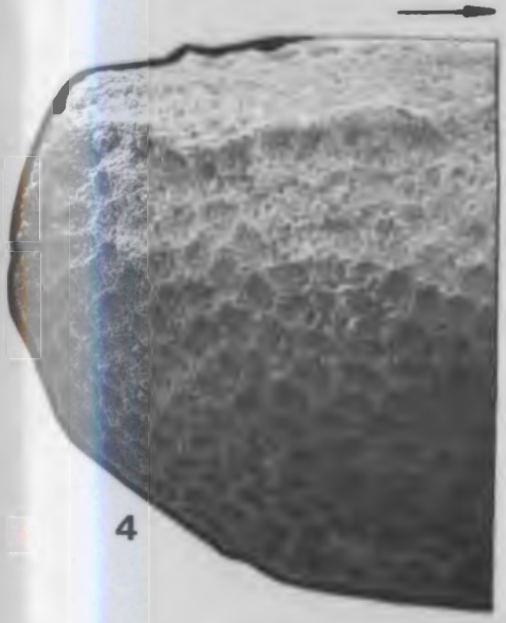

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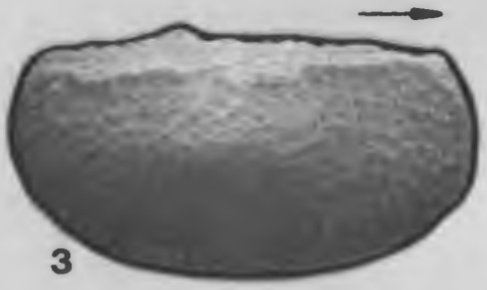

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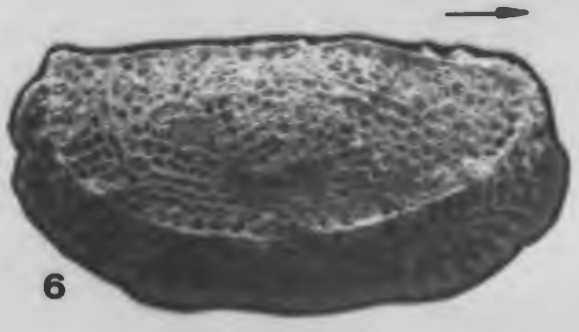

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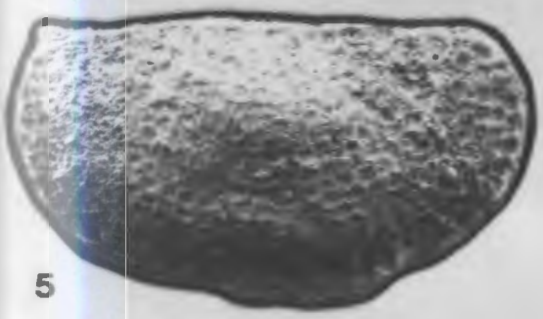

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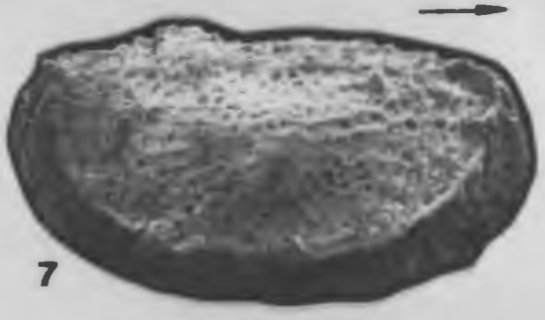

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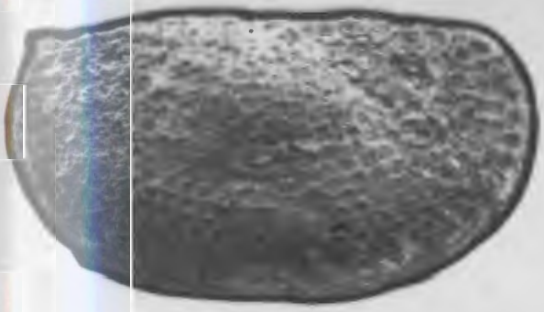

8

PLATE 3

figs. 1,1a *Aechmina* sp.?: fig. 1, left aspect, 0°, fig. 1a, left aspect, 10°, magnification about 65.

figs. 2 - 6 *Kirkbya* n. sp. A.: fig. 2, right aspect; fig. 3, left aspect; fig. 4, ventral view; fig. 5, anterior view, magnification about 65; fig. 6, enlargement of marginal carina in fig. 5, magnification about 250.

figs. 1, 1a, are a steinkern

figs. 2 - 6 are carapace material.

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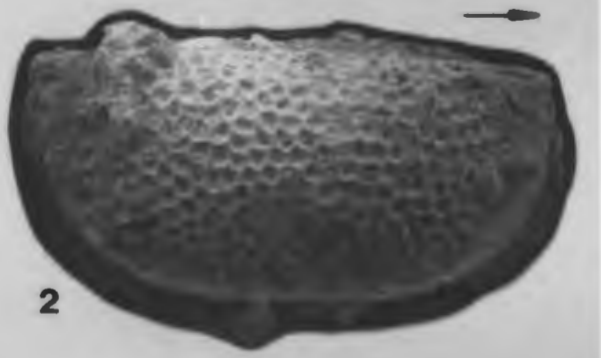

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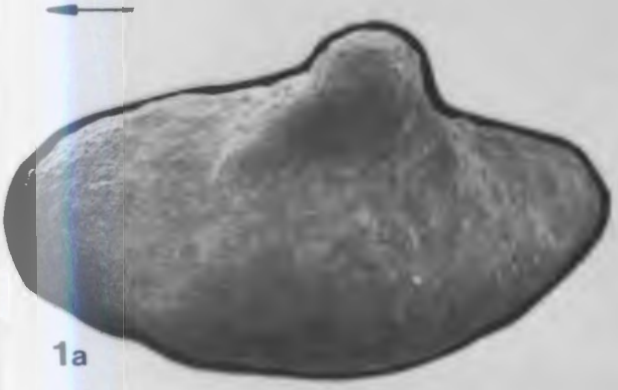
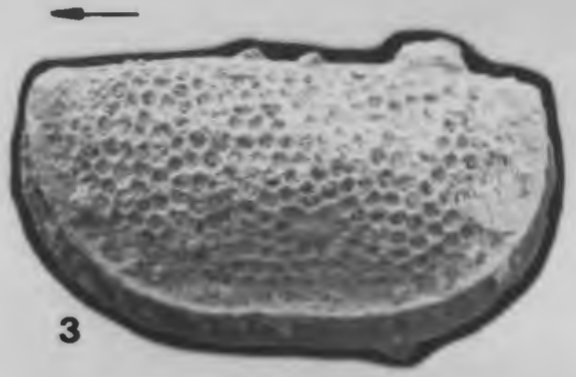


1a



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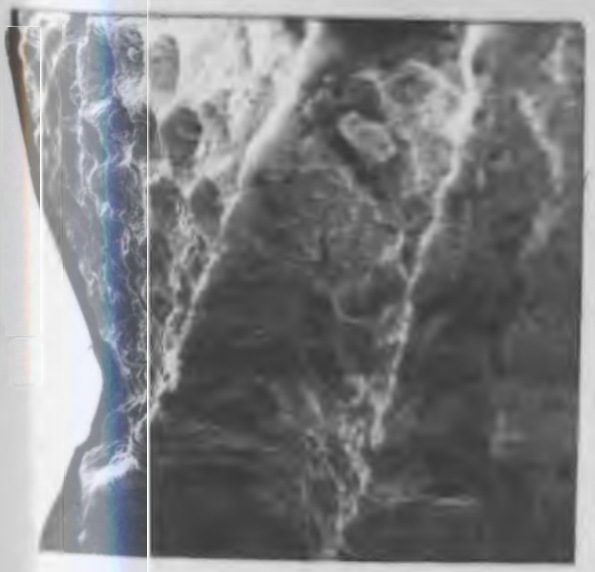

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PLATE 4

figs. 1,1a,2 *Kirkbya* n. sp. A.: fig. 1, left aspect, 0°; fig. 1a, left aspect, 10°; fig. 2, dorsal view, magnification about 60.

figs. 3,4 *Kirkbya* n. sp. A.: interior of left valve, magnification about 45; fig. 4, enlargement of posterior end, magnification about 200.

figs. 5,6 *Kirkbya* n. sp. A.: fig. 5, right aspect, magnification about 55; fig. 6, enlargement of "kirkbyan" pit, magnification about 235.

All figures are carapace material.

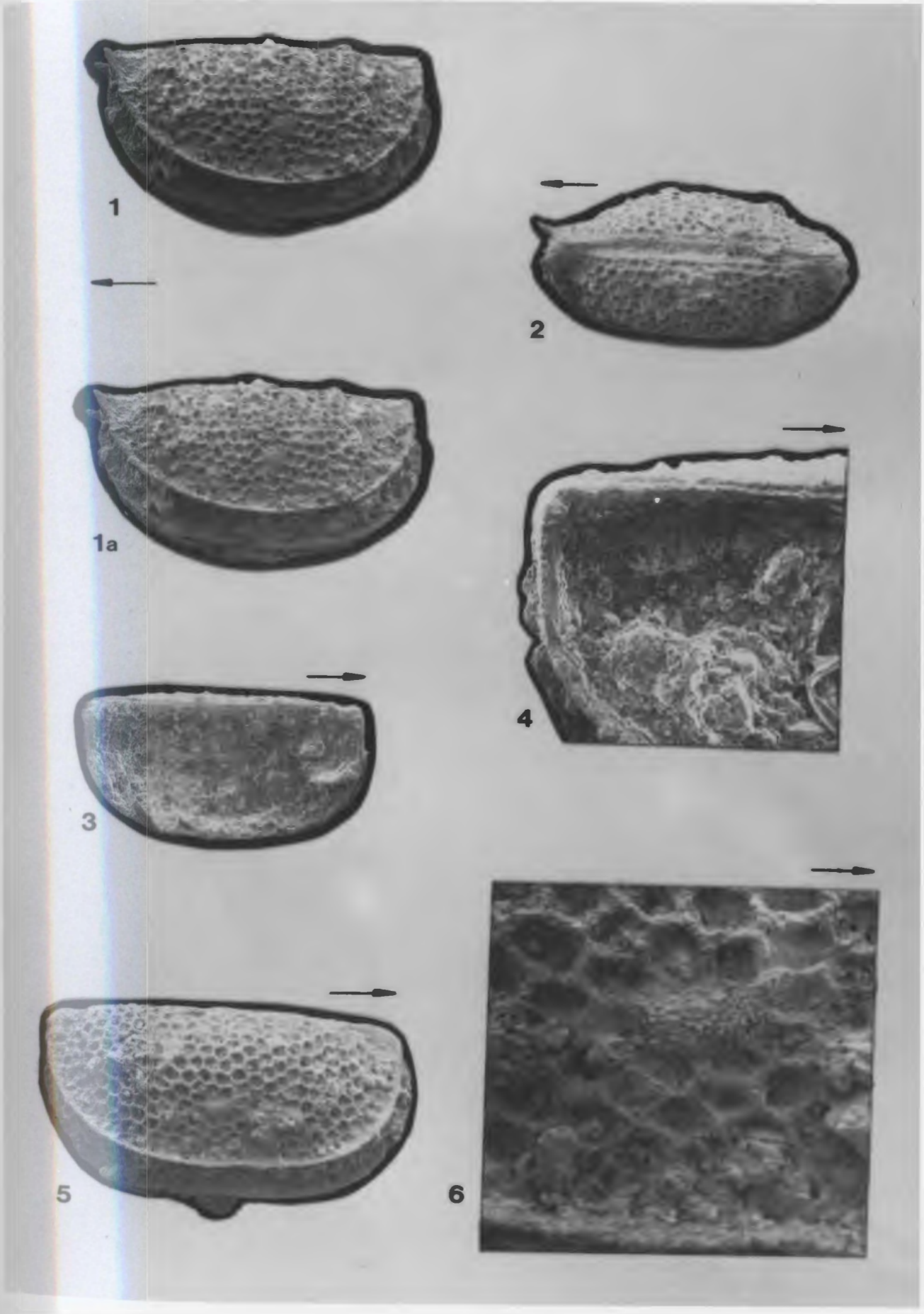
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PLATE 5

figs. 1,2 *Youngiella* sp.: fig. 1, dorsal view; fig. 2, left aspect, magnification about 140.

figs. 3,4 *Youngiella* sp.: fig. 3, dorsal view; fig. 4, right aspect, magnification about 155.

figs. 5 - 8 *Bairdia brevis*: fig. 5, right aspect; fig. 6, left aspect; fig. 7, dorsal aspect; fig. 8, ventral view, magnification about 55.

fig. 9 *Bairdia brevis*: right aspect, magnification about 65.

fig. 10 *Bairdia brevis*: right aspect, magnification about 65.

figs. 1 - 4 are steinkerns

figs. 5 - 10 are carapace material.


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PLATE 6

figs. 1 – 4 *Bairdia* sp. L.: right aspect, magnification about 50; fig. 2, left aspect, magnification about 55; fig. 3, right aspect in transmitted light, magnification about 50; fig. 4, ventral view, magnification about 55.

figs. 5,6 *Bairdia* sp. L.: fig. 5, right aspect; fig. 6, dorsal view, magnification about 40.

figs. 7,8 *Bairdia* sp. L.: fig. 7, right aspect, magnification about 45; fig. 8, left aspect, magnification about 50.

figs. 9.10 *Bairdiacypris quartziana*: fig. 9, right aspect; fig. 10, left aspect; magnification about 45.

figs. 11,12 *Bairdiacypris quartziana*: fig. 11, right aspect; fig. 12, dorsal view, magnification about 45.

figs. 13,14 *Bairdiacypris quartziana*: fig. 13, ventral view, fig. 14, right aspect, magnification about 45.

All apecimens are carapace material.

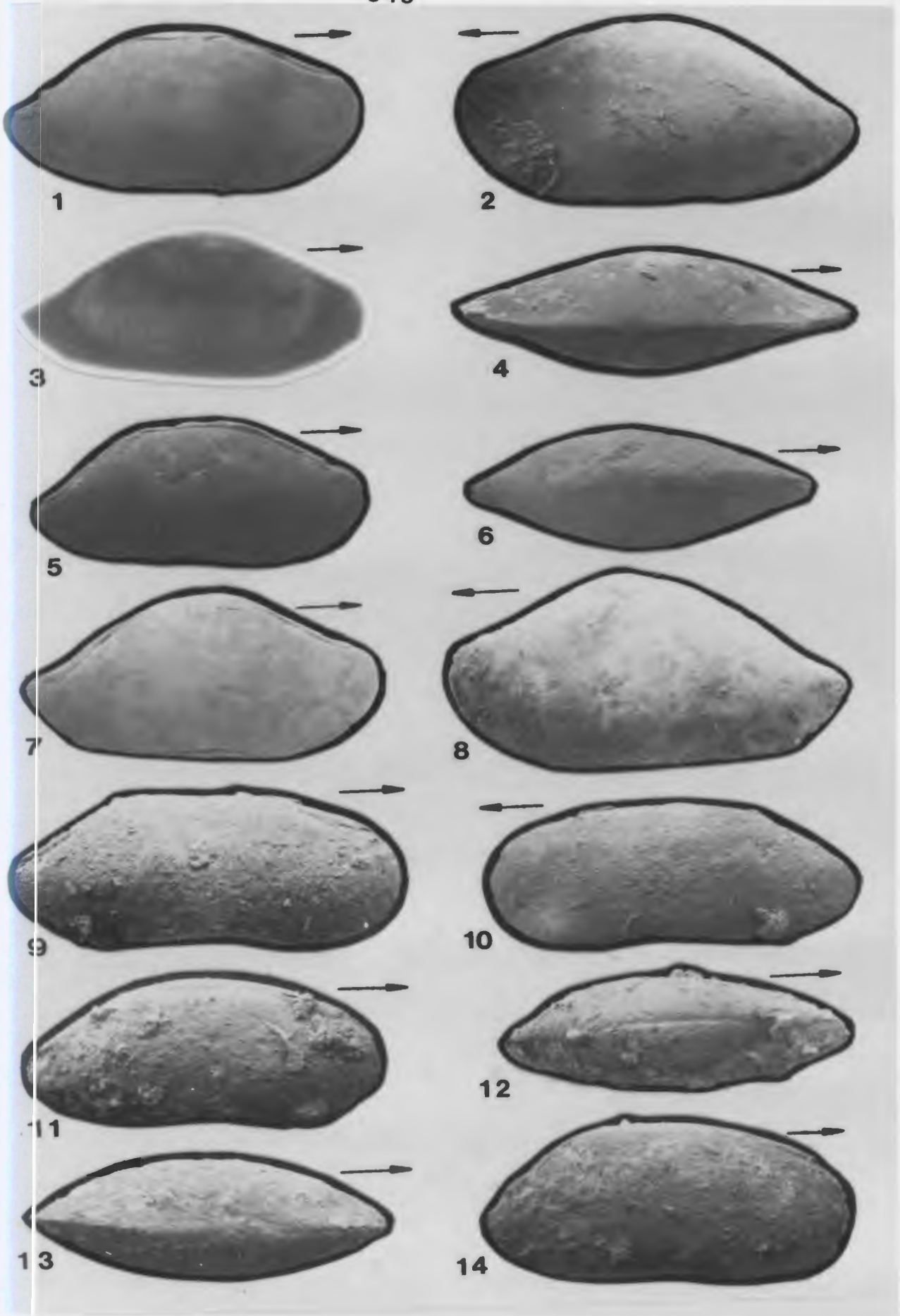
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PLATE 7

figs. 1 - 3 *Acutiangulata aequalis*: fig. 1, dorsal view; fig. 2, right aspect; fig. 3, ventral view, magnification about 60.

fig. 4 *Acutiangulata aequalis*: fig. 4, interior of left valve, magnification about 70.

figs. 5,6 *Acutiangulata* n. sp. A.: fig. 5, doesal view; fig. 6, ventral view, magnification about 85.

figs. 7,8 *Acutiangulata* n. sp. A.: fig. 7, right aspect. fig. 8, dorsal view, magnification about 70.

fig. 9 *Acutiangulata* n. sp. A.: fig. 9, right aspect, magnification about 95.

figs. 1 - 4 are carapace material.
figs. 5,6 are steinkerns and figs. 7 - 9 are partially exfoliated specimens.

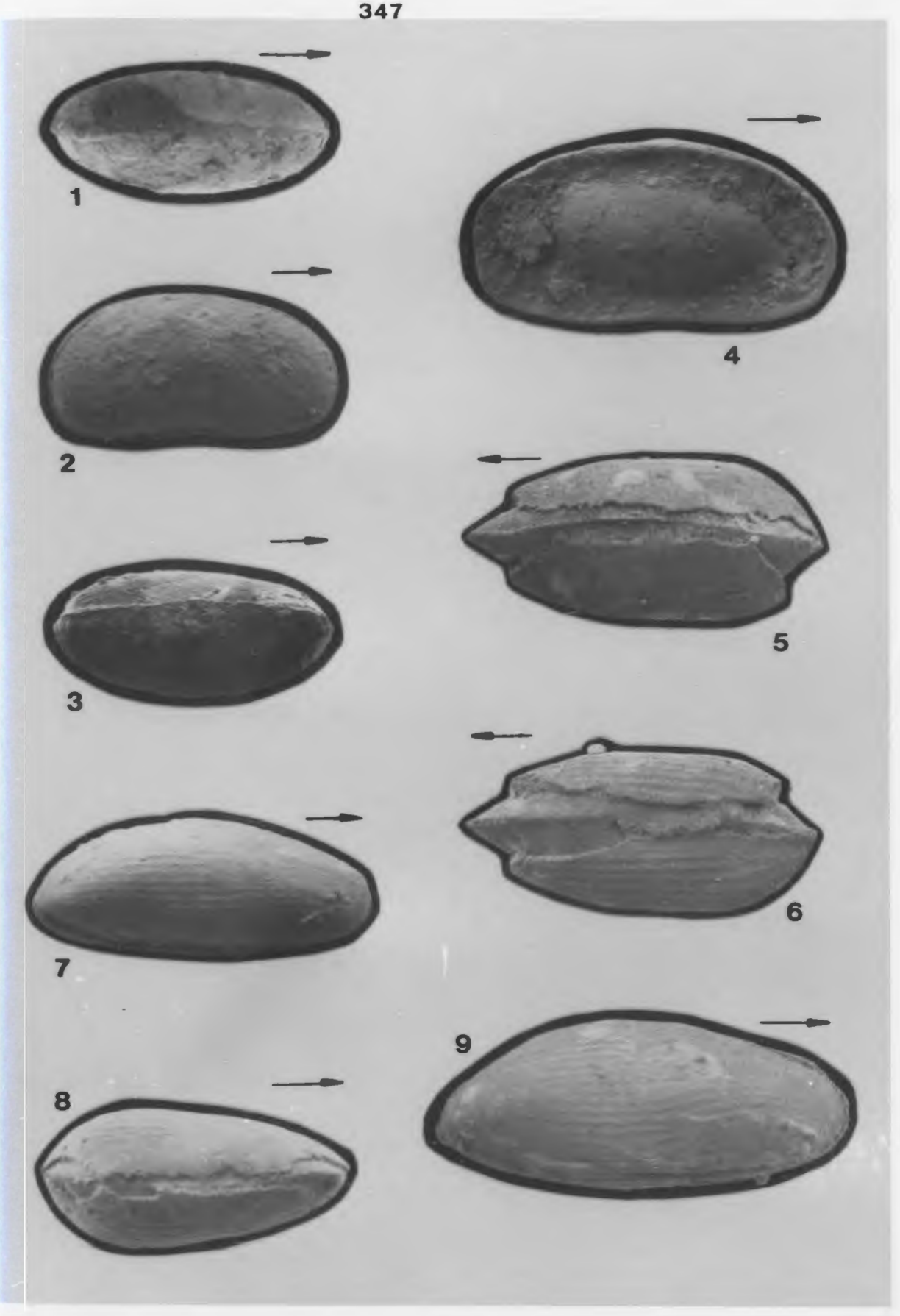
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PLATE 8

figs. 1 - 4 *Acratia acuta*: fig. 1, left aspect; fig. 2, right aspect; fig. 3, ventral view; fig. 4, dorsal view, magnification about 65.

fig. 5 *Acratia acuta*: fig. 5, right aspect; fig. 6, dorsal view, magnification about 85.

fig. 7 *Acratia acuta*: fig. 7, left aspect, magnification about 65.

figs. 8 - 11 *Monoceratina antiqua*: fig. 8, left aspect; fig. 9, right aspect; fig. 10, ventral view; fig. 11, dorsal view, magnification about 62.

figs. 1 - 7 are carapace material.

figs. 8 - 11 are a steinkern.

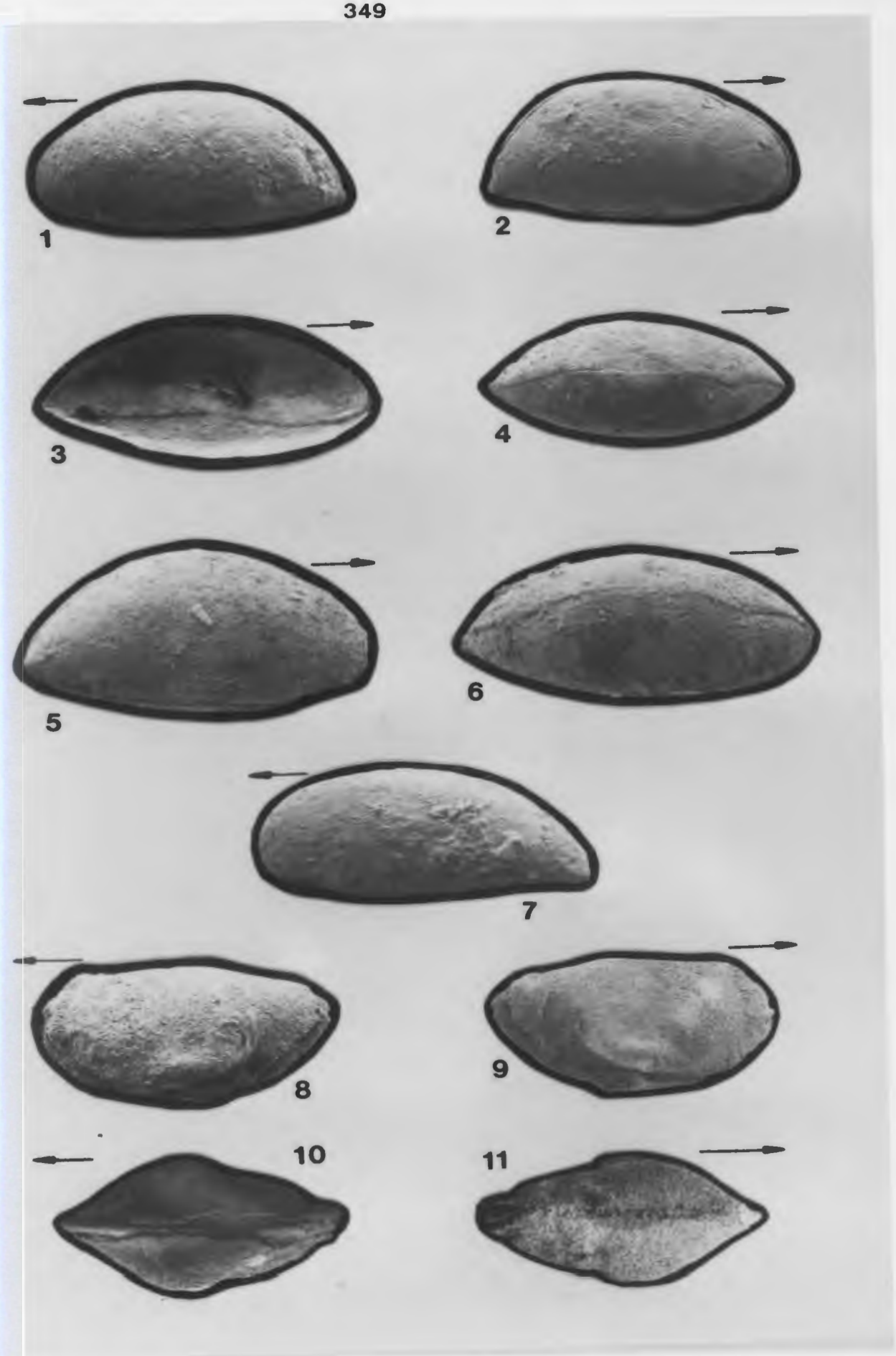
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PLATE 9

figs. 1 - 5 *Monoceratina youngiana*: fig. 1, interior view of right valve; fig. 4, exterior view of right valve, magnification about 120; fig. 2, enlargement of posterior dorsal corner; fig. 3, enlargement of anterior ventral corner, magnification about 865; fig. 5, posterior portion of right valve, exterior view, magnification about 300.

figs. 6 - 8 *Bassleralla obesa*: fig. 6, left aspect; fig. 7, right aspect; fig. 8, dorsal view, magnification about 55.

figs. 1 - 5 are carapace material.
figs. 6 - 8 are a steinkern.

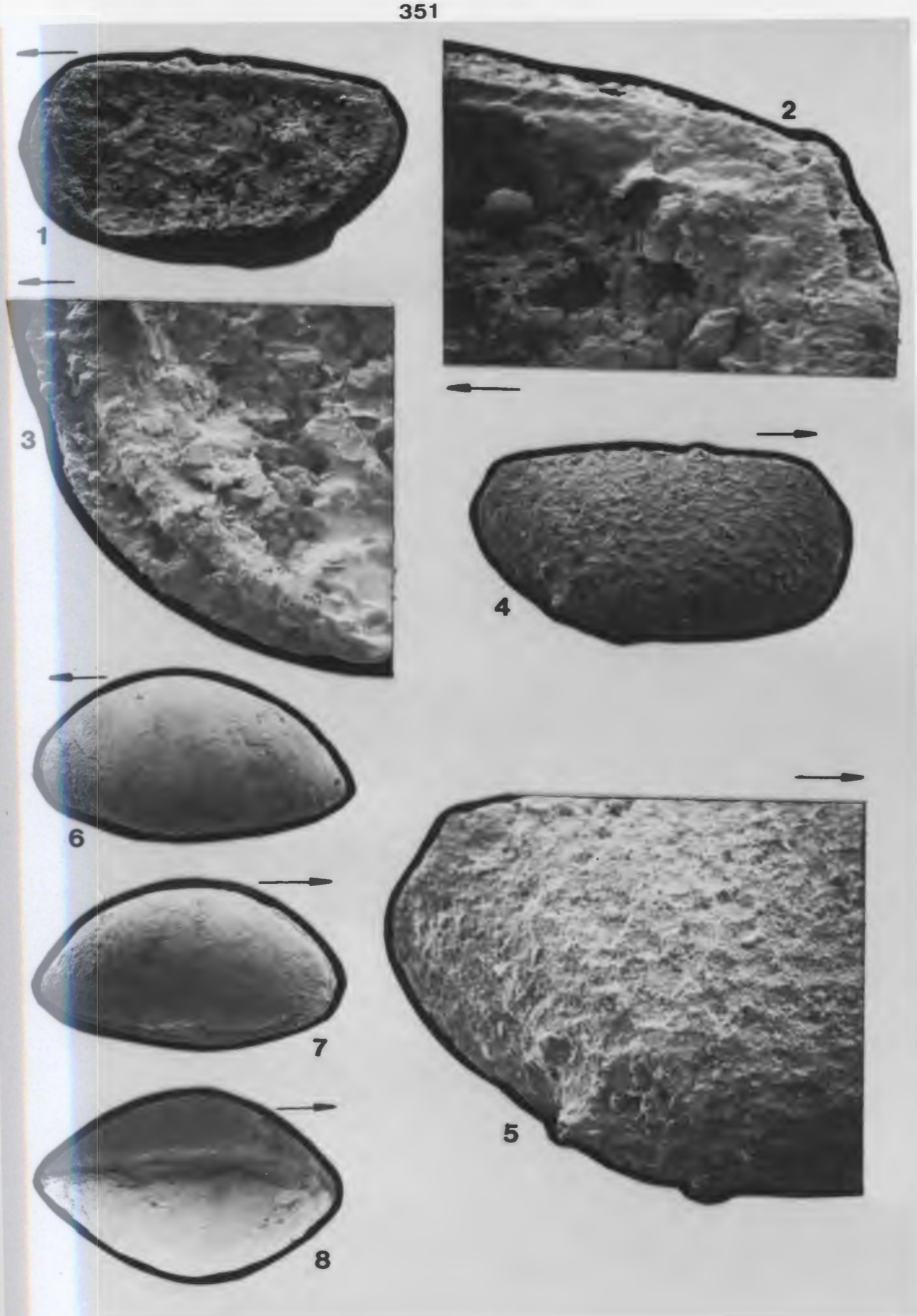
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PLATE 10

figs. 1 - 3 *Bassleralla firma*: fig. 1, left aspect; fig. 2, right aspect; fig. 3, dorsal view. magnification about 65.

figs. 4 - 6 *Bassleralla firma*: fig. 4, right aspect; fig. 5, dorsal view; fig. 6, ventral view, magnification about 65.

fig. 7 *Geisina* sp.: right aspect, magnification about 90.

fig. 8 *Geisina* sp.: left aspect, magnification about 90.

fig. 9 *Geisina* sp.: dorsal view, magnification about 90.

figs. 1 - 3 are a steinkern.

figs. 4 - 6 are carapace material.

figs. 7 - 9 are corroded carapace material.

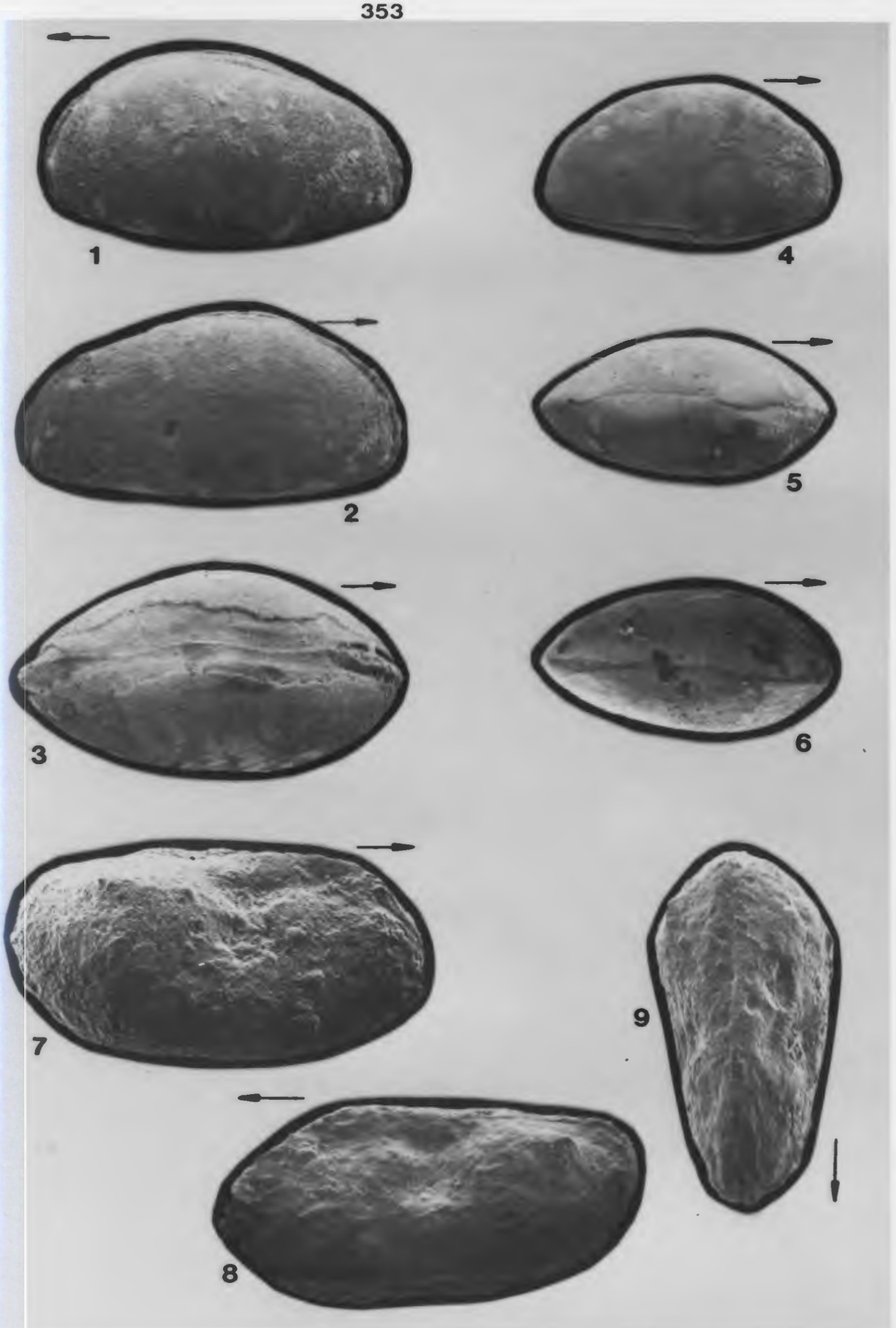
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Plate 11

figs. 1 - 4 *"Neokloedenella" variolata*: fig. 1, left aspect; fig. 2, right aspect; fig. 3, ventral view; fig. 4, dorsal view; magnification about 60.

figs. 5,6 *"Neokloedenella" variolata*: fig. 5, interior of left valve, magnification about 60; fig. 6, enlargement of posterior end, magnification about 230.

figs. 7,8 *"Neokloedenella" variolata*: fig. 7, left aspect, fig. 8, dorsal view, magnification about 55.

figs. 1 - 8 are carapace material.

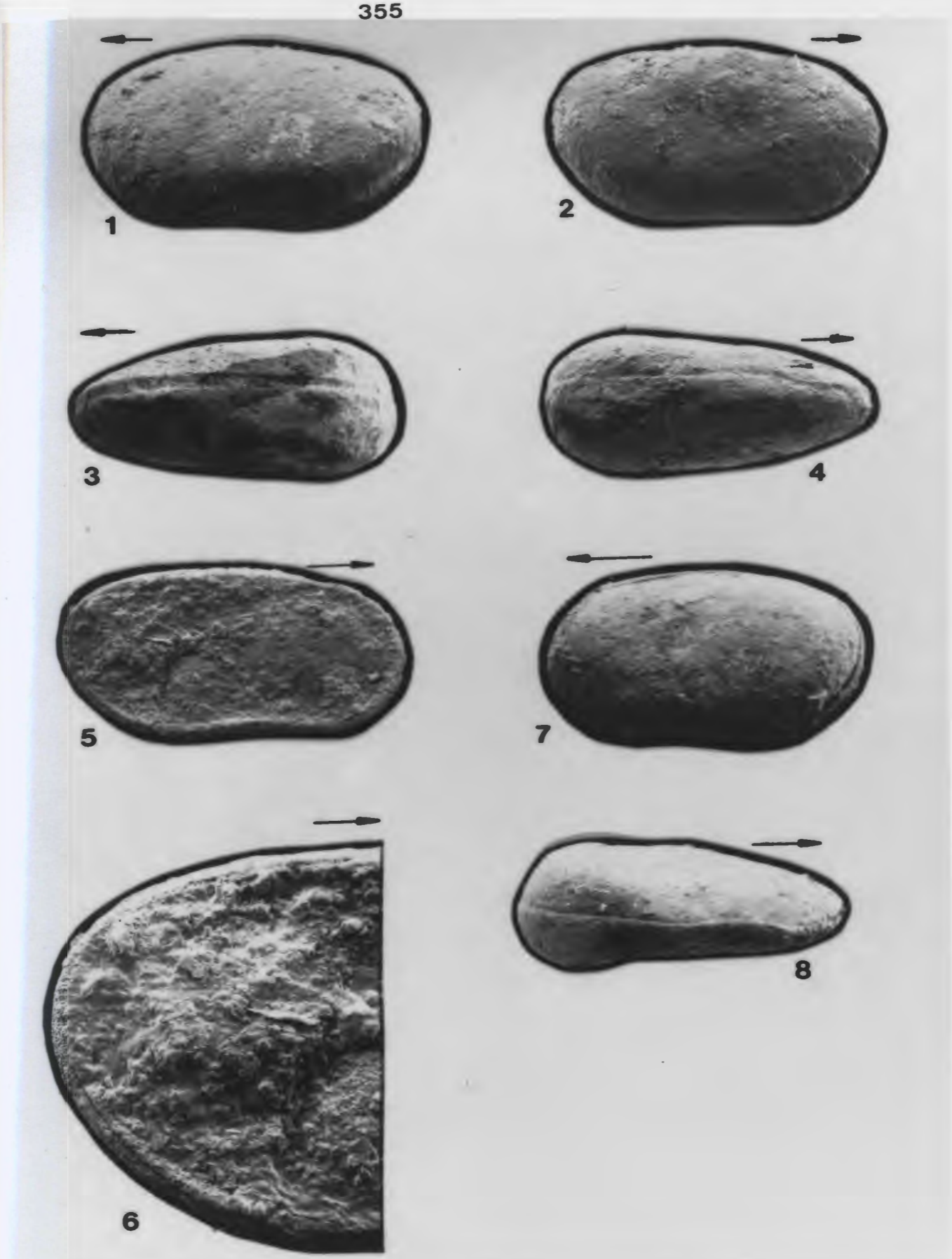
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PLATE 12

figs. 1 - 5 *Beyrichiopsis lophota*: fig. 1, left aspect, 0°;
fig. 1a, left aspect, 10°;
fig. 2, right aspect, 0°;
fig. 2a, right aspect, 10°;
fig. 4, dorsal view;
fig. 5, ventral view,
magnification about 60;
fig. 3, enlargement of
anterior end of left valve,
magnification x 310.

figs. 1 - 5 are carapace material.

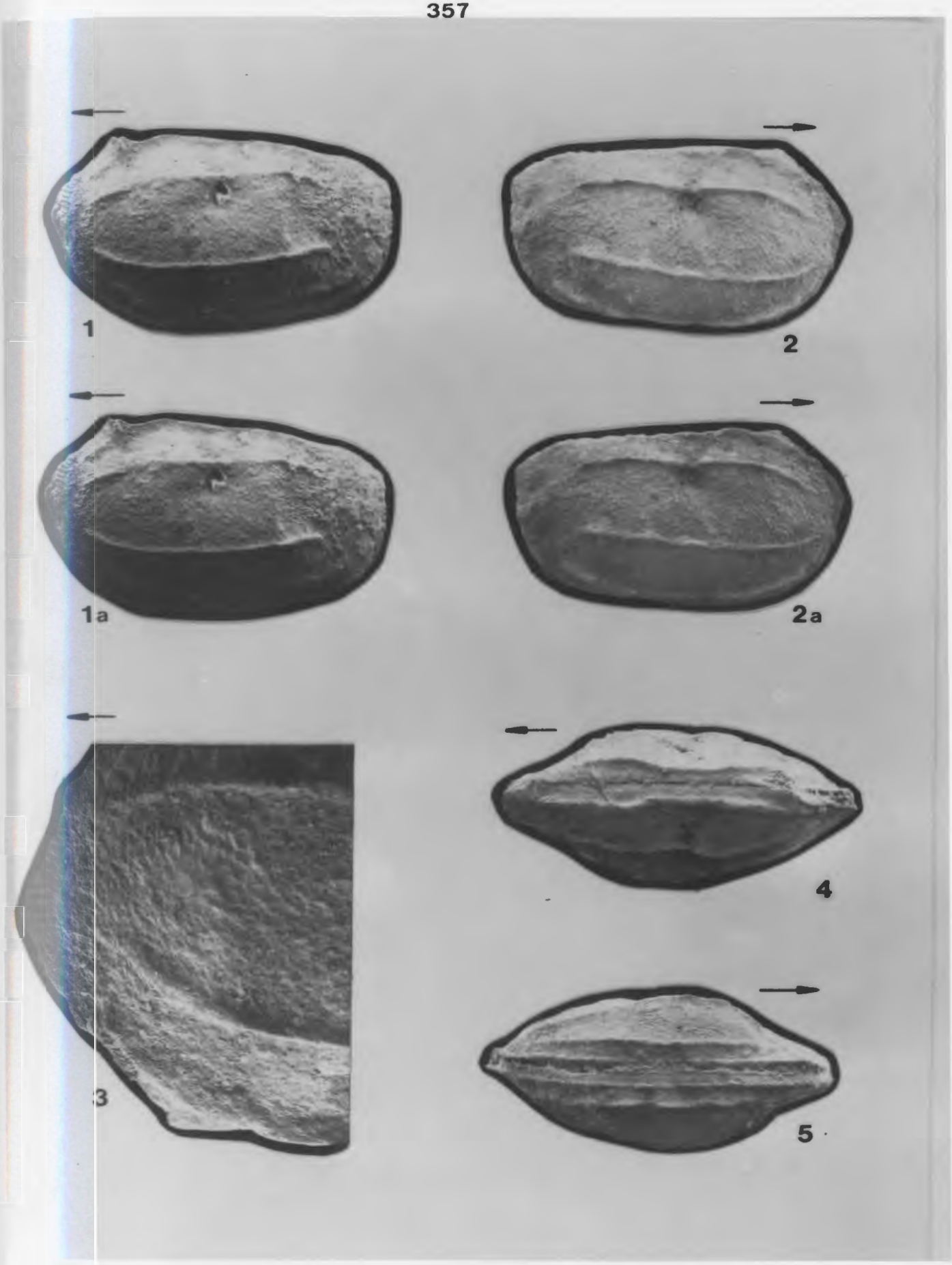
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PLATE 13

figs. 1 - 3 *Beyrichiopsis cornuta*: fig. 1, dorsal view; fig. 2, left aspect, 0°; fig. 2a, left aspect, 10°, magnification about 70; fig. 3, enlargement of anterior margin of left valve, magnification about 230.

figs. 4 - 6 kloedenellacean gen. et sp. indet. 1: fig. 4, dorsal view; fig. 5, right aspect; fig. 6, left aspect, magnification about 90.

figs. 1 - 3 are carapace material.
figs. 4 - 6 are a silicified specimen.

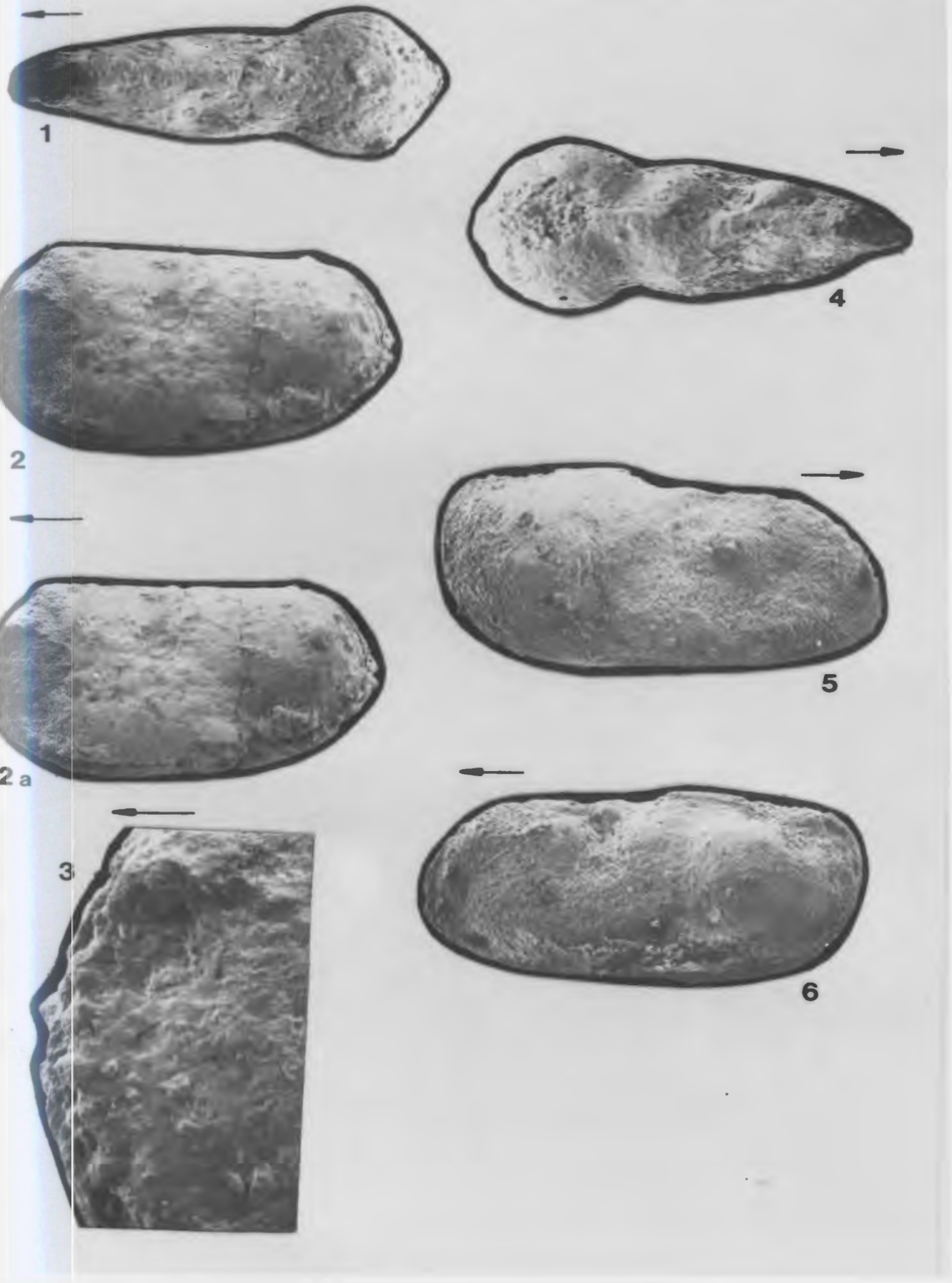
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PLATE 14

fig. 1 *Healdia* sp.?: right aspect, magnification about 60.

figs. 2,3 *Healdia* sp.?: fig. 2, left aspect; fig. 3, dorsal view, magnification about 55.

figs. 4 - 7 *Healdia* sp.?: fig. 4, dorsal view; fig. 5, left aspect; fig. 6, right aspect, magnification about 65; fig. 7, enlargement of muscle scar field in fig. 6, magnification about 240.

figs. 8 - 11 bairdiocypridid gen. et sp. indet. 2: fig. 8, right aspect; fig. 9, left aspect; fig. 10, dorsal view; fig. 11, ventral view, magnification about 80.

figs. 1 - 7 are steinkerns.

figs. 8 - 11 are a steinkern.

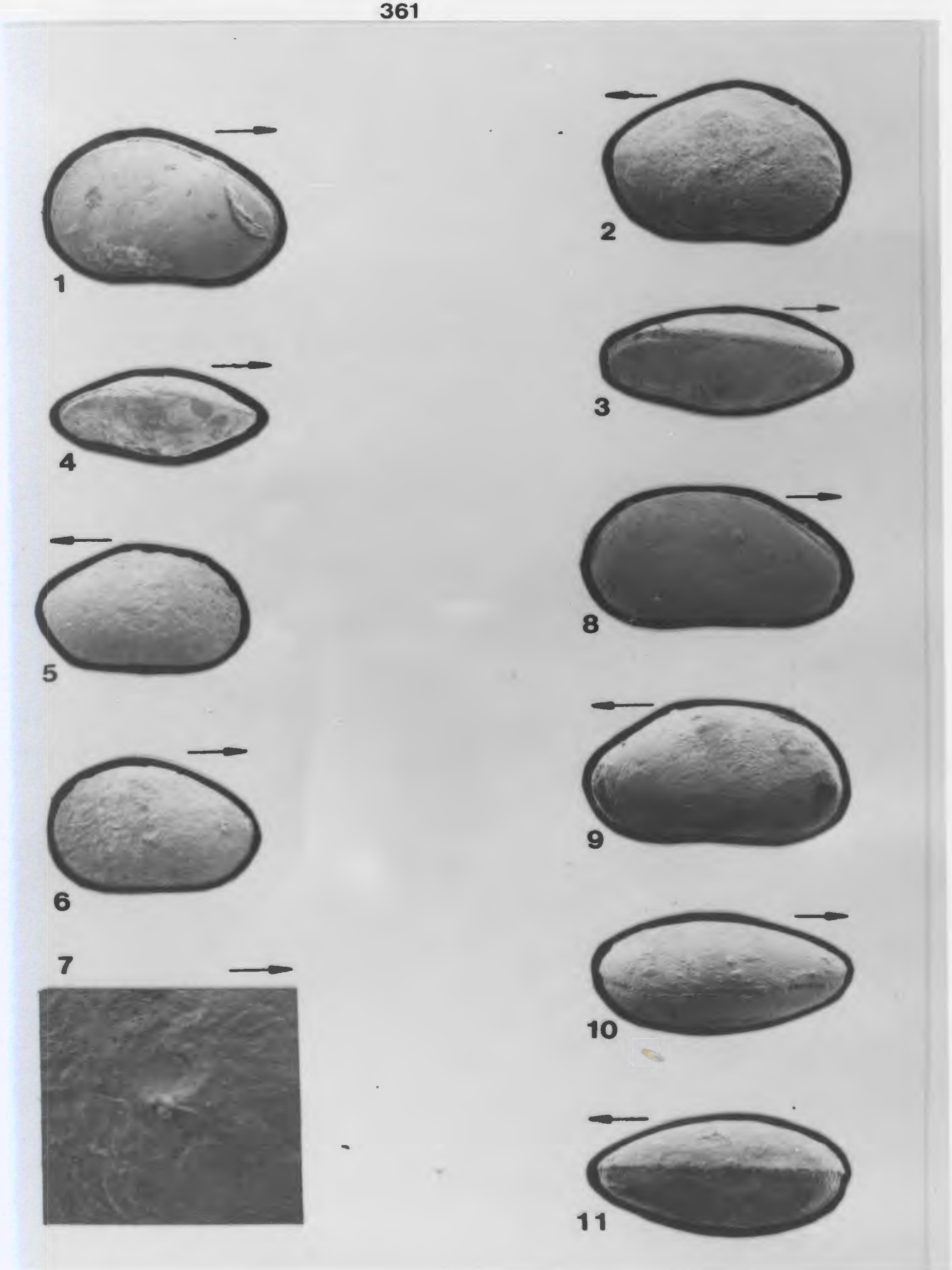
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PLATE 15

figs. 1,2 *Shemonaella scotoburdigalensis*: fig. 1, right aspect, fig. 2, dorsal view, magnification about 40.

figs. 3 - 7 *Paraparchites* sp. aff. *P. kellettae*: fig. 3, right aspect; fig. 4, left aspect; fig 5, dorsal view; fig. 6, ventral view; fig. 7, posterior view, magnification about 25.

figs. 1 - 2 are a partially exfoliated specimen.
figs. 3 - 7 are a partially exfoliated specimen.

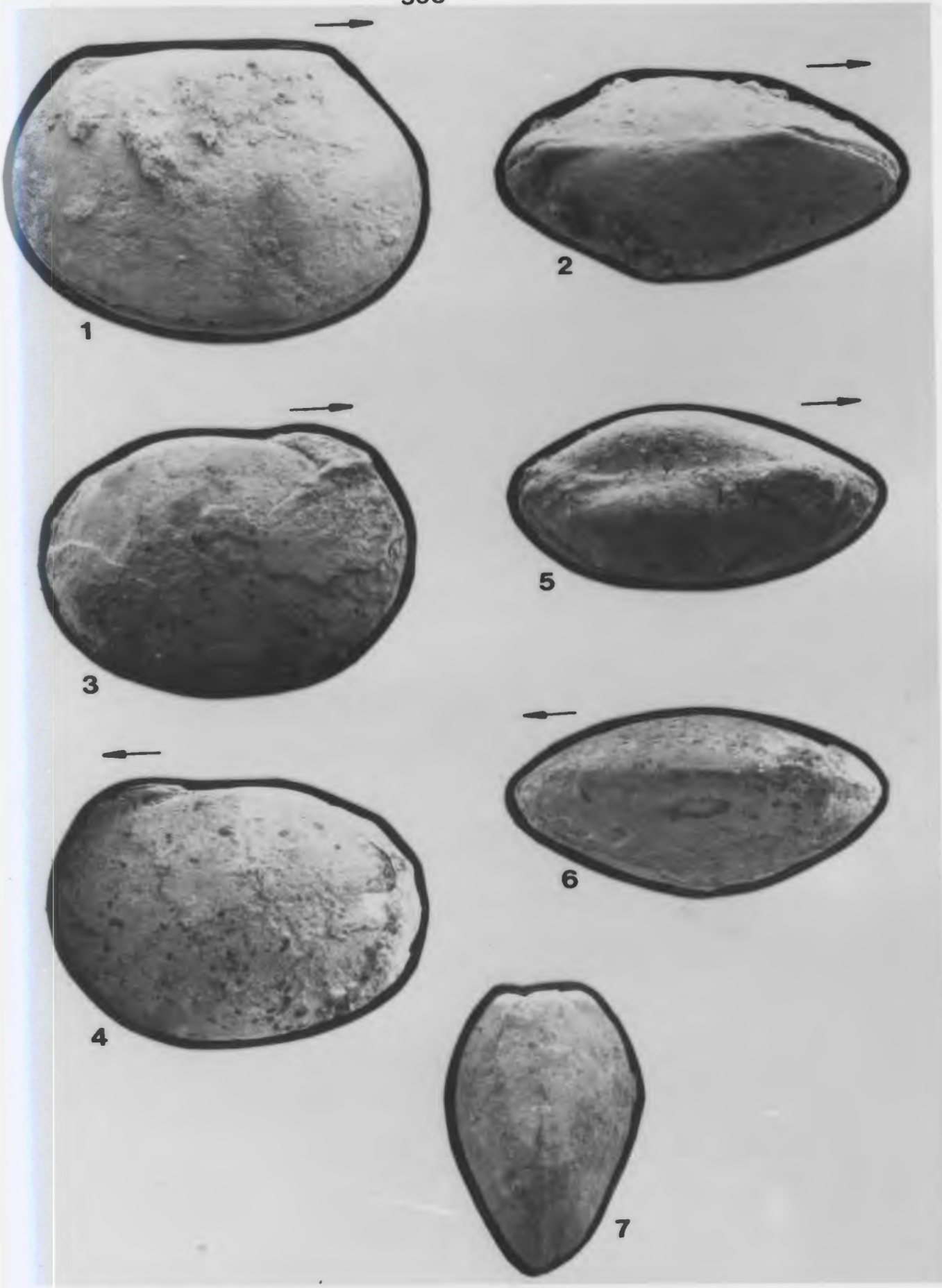
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PLATE 16

figs. 1 - 5 *Paraparchites* sp. aff. *P. kellettae*: fig. 1, right aspect, 0°; fig. 1a, right aspect, 8° stereo pair; fig. 2, left aspect; fig. 3, dorsal view; fig. 4, ventral view; fig. 5, posterior view, magnification about 30.

figs. 1 - 5 are a steinkern.

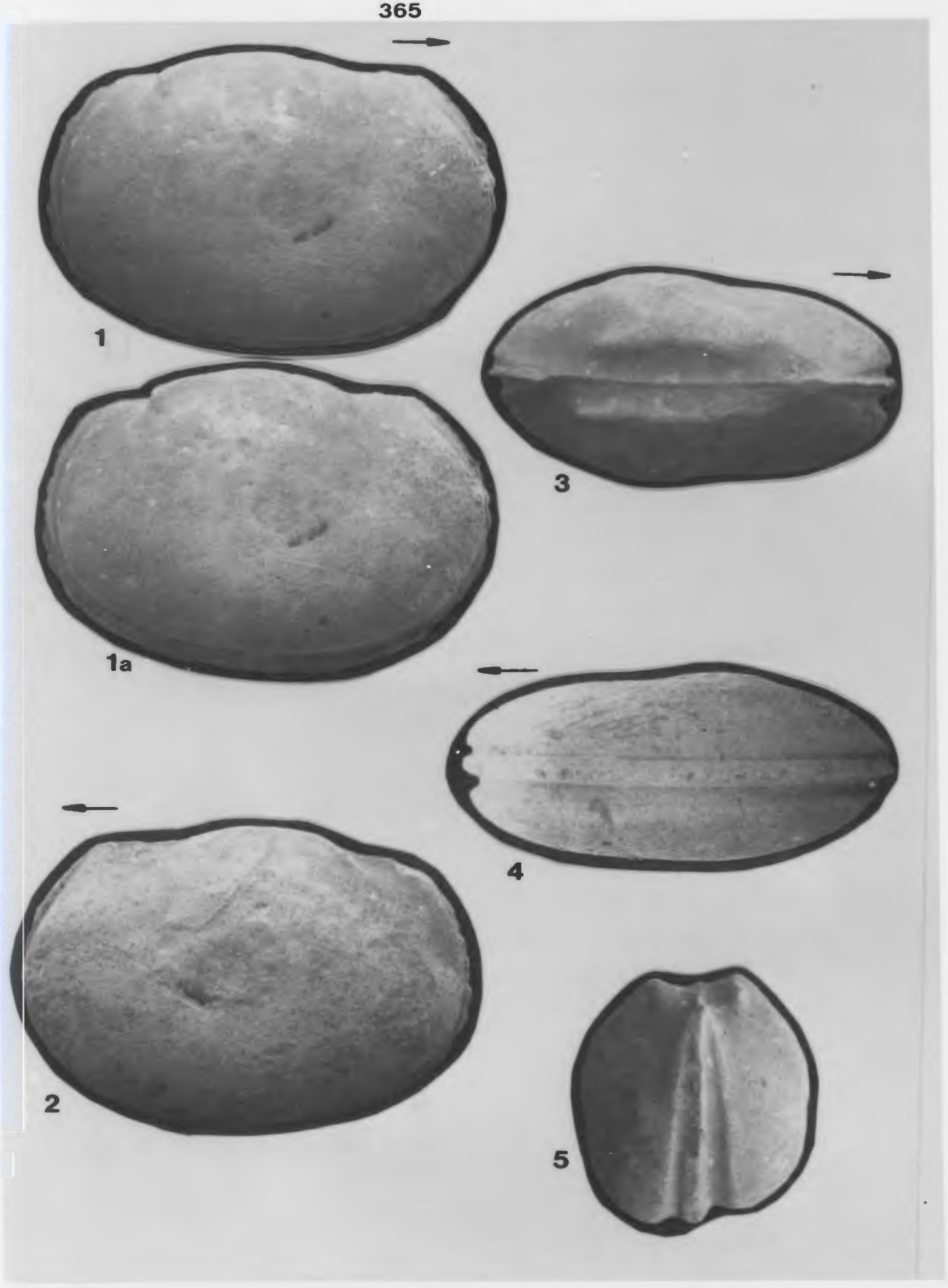
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PLATE 17

figs. 1,2 *Paraparchites* sp. aff. *P. kellettae*: fig. 1, broken carapace infilled by gypsum, wall about 175μm thick, magnification about 20; fig. 2, enlargement of dorso-median wall of left valve, magnification about 285.

figs. 3 - 5 *Paraparchites* sp. aff. *P. kellettae*: fig. 3, broken carapace infilled by gypsym, wall about 250μm thick, magnification about 20; fig. 4, enlargement of dorsal portion showing hinge, magnification about 220; fig. 5, dorso-lateral wall of left? valve, magnification about 220.

figs. 1 - 5 are carapace material.

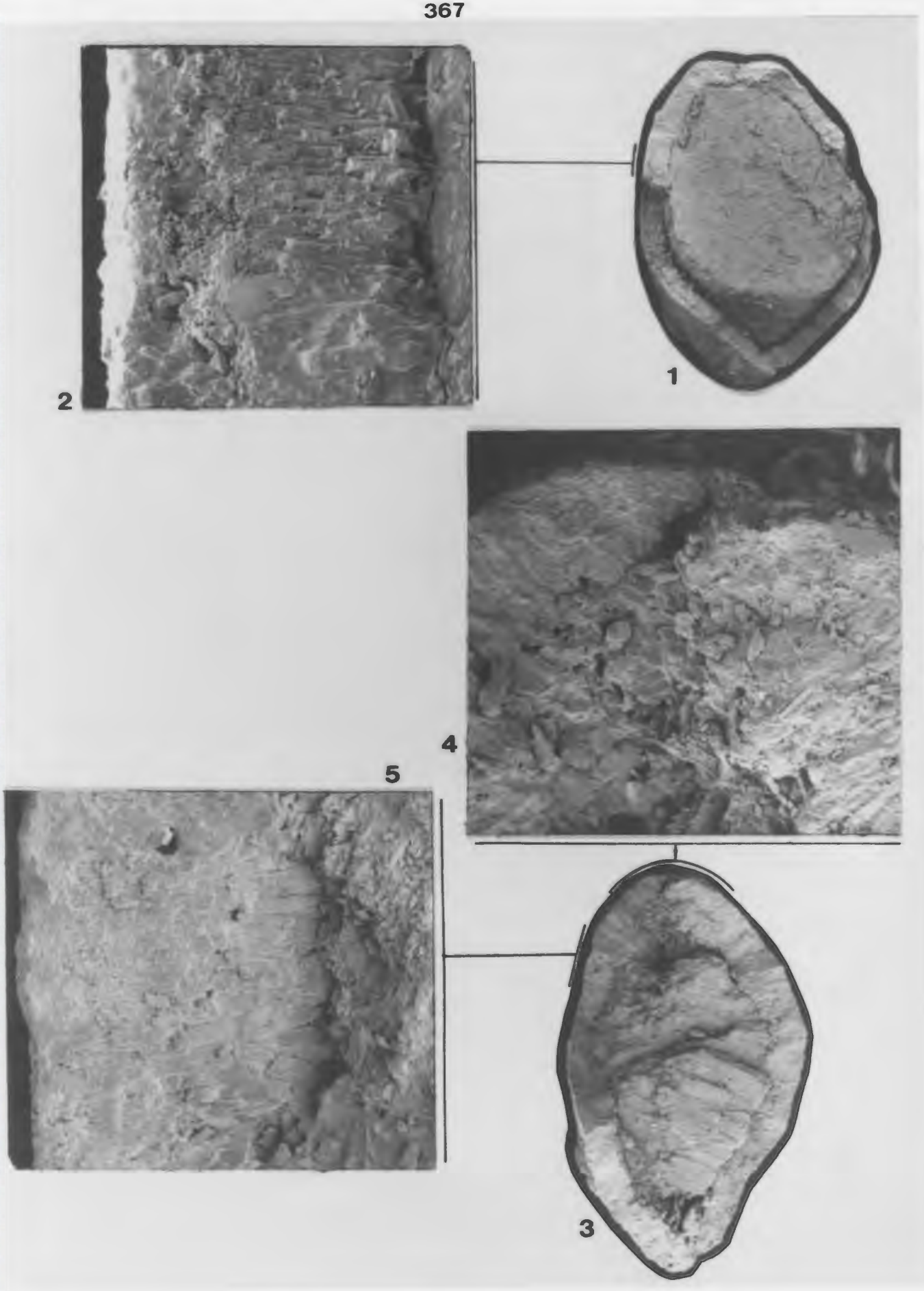
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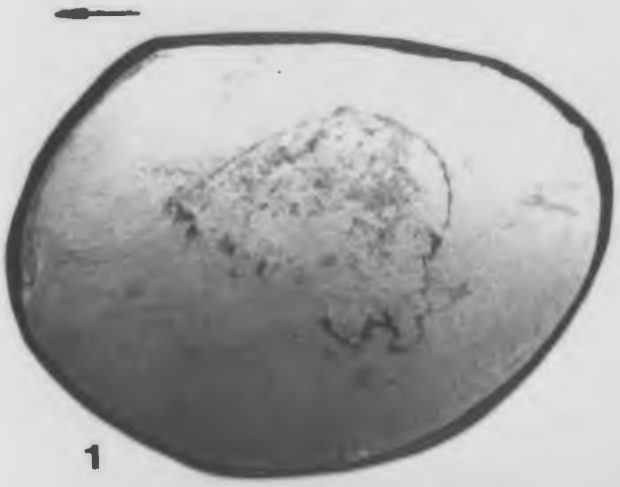
PLATE 18

figs. 1 – 5 *Chamishaella suborbiculata*: fig. 1, left aspect;
fig. 2, right aspect;
fig. 3, dorsal view;
fig. 4, ventral view;
fig. 5, posterior view,
magnification about 45.

figs. 6,7 *Chamishaella suborbiculata*: fig. 6, right aspect;
fig. 7, posterior view;
magnification about 60.

figs. 1 – 5 are a steinkern.

figs. 6,7 are a steinkern.



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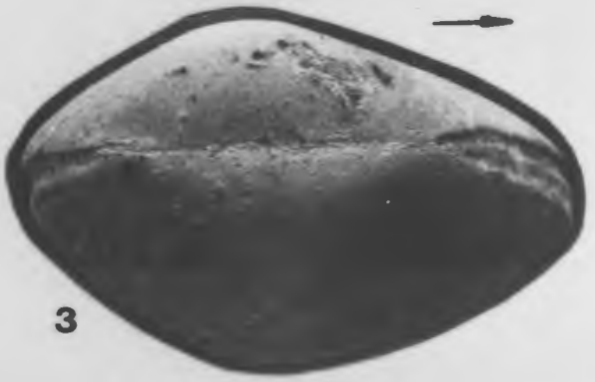

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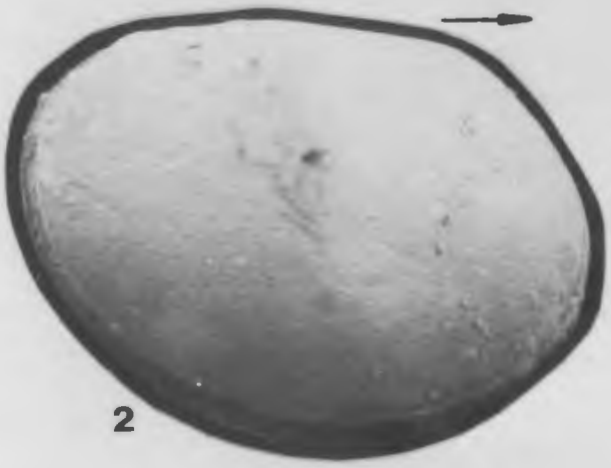

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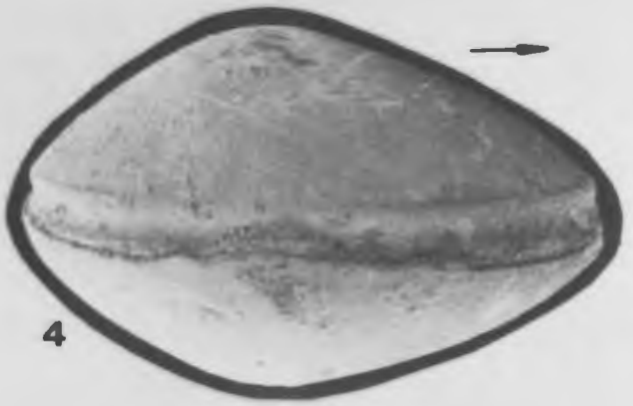

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PLATE 19

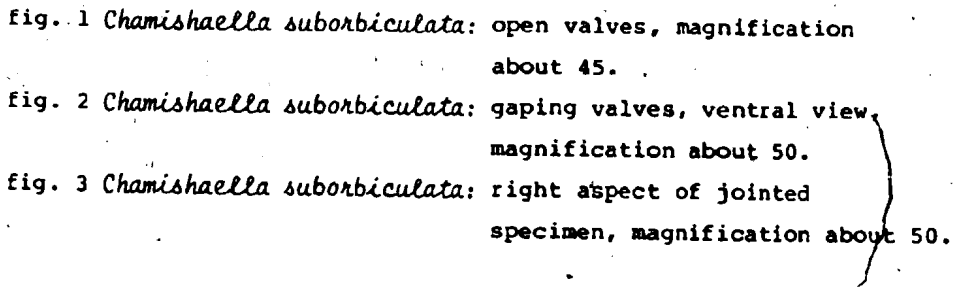

fig. 1 *Chamishaella suborbiculata*: open valves, magnification about 45.

fig. 2 *Chamishaella suborbiculata*: gaping valves, ventral view, magnification about 50.

fig. 3 *Chamishaella suborbiculata*: right aspect of jointed specimen, magnification about 50.

fig. 4 *Shivaella* sp.: left aspect, magnification about 70.

fig. 5 *Shivaella* sp.: dorsal view, magnification about 65.

fig. 6 *Shivaella* sp.: posterior view, magnification about 85.

fig. 1 is a cast

fig. 2 is carapace material.

fig. 3 is steinkern material.

figs. 4 - 6 are steinkern material.

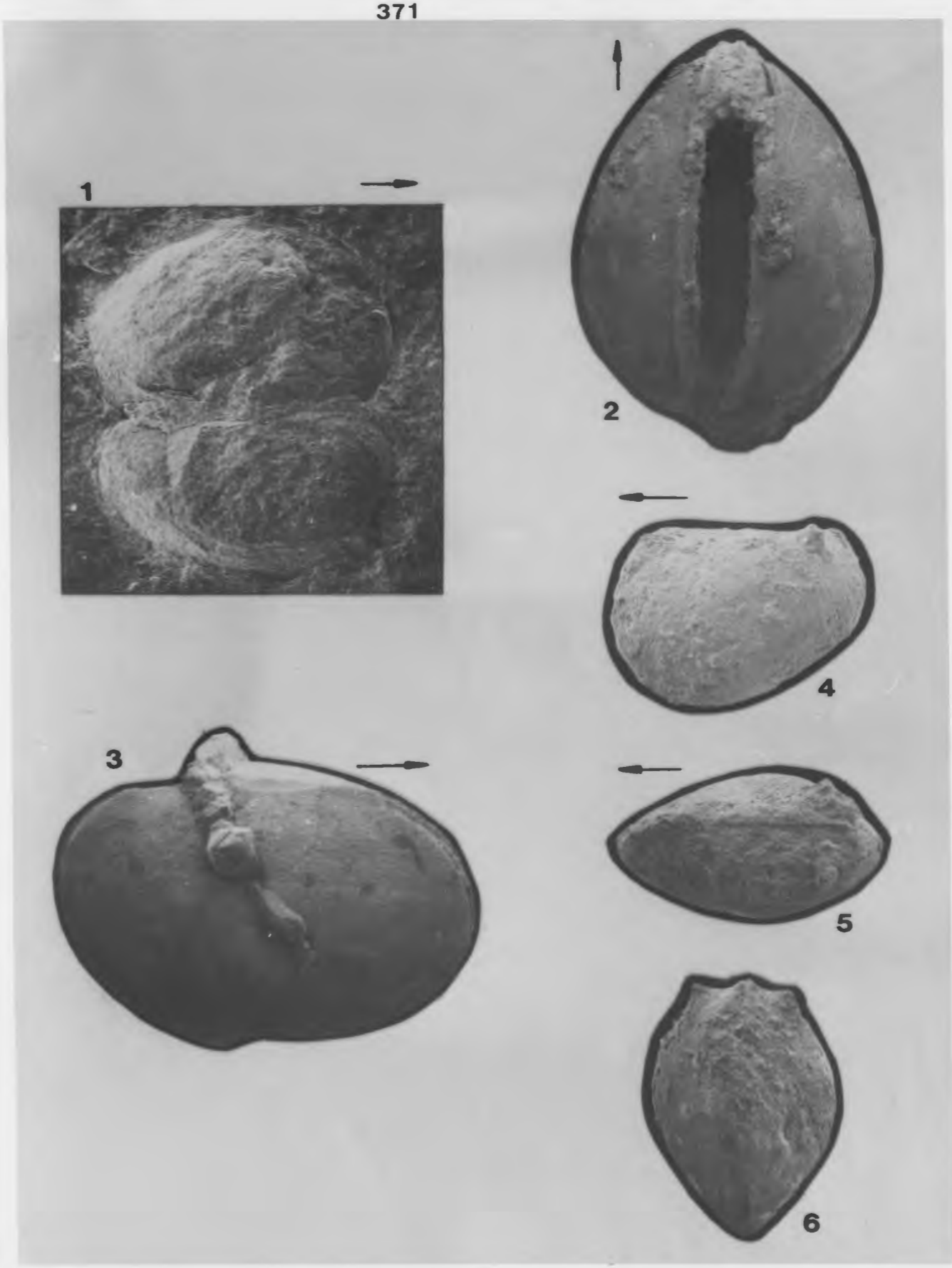
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PLATE 20

fig. 1 *Chamishaella* n. sp. A.: interior of left valve, magnification about 40, posterior end and anterior ends, magnification about 85.

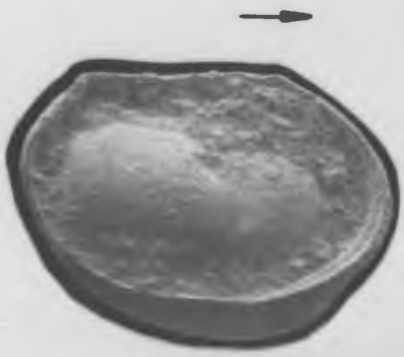
figs. 2,3 *Chamishaella* n. sp. A.: fig. 2, right aspect; fig. 3, juvenile ventral view, magnification about 45.

figs. 4,5 *Chamishaella* n. sp. A.: fig. 4, right aspect; fig. 5, female ventral view, magnification about 45.

fig. 6 *Chamishaella* n. sp. A.: fig. 6, posterior view, magnification about 40.

fig. 1 is carapace material.
figs. 2 - 6 are steinkerns.

1



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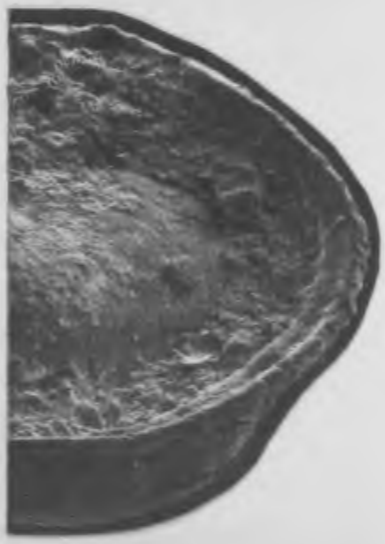

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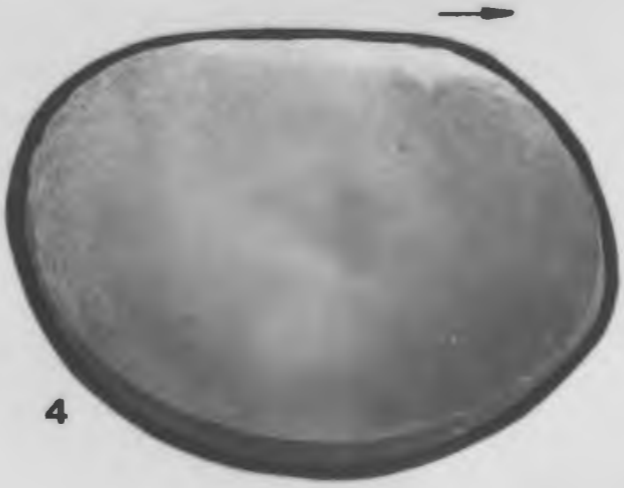
2



4

3

5

6

PLATE 21

figs. 1 - 3 *Shishaella moreyi*: fig. 1, right aspect, 0°; fig. 1a, right aspect, 8°; stereo pair; fig. 2, dorsal view; fig. 3, posterior view, magnification about 35.

figs. 4 - 7 *Shishaella moreyi*: fig. 4, right aspect; fig. 5, left aspect; fig. 6, dorsal view; fig. 7 posterior view, magnification a about 55.

figs. 1 - 3 are a partially exfoliated specimen.

figs. 4 - 7 are a steinkern.

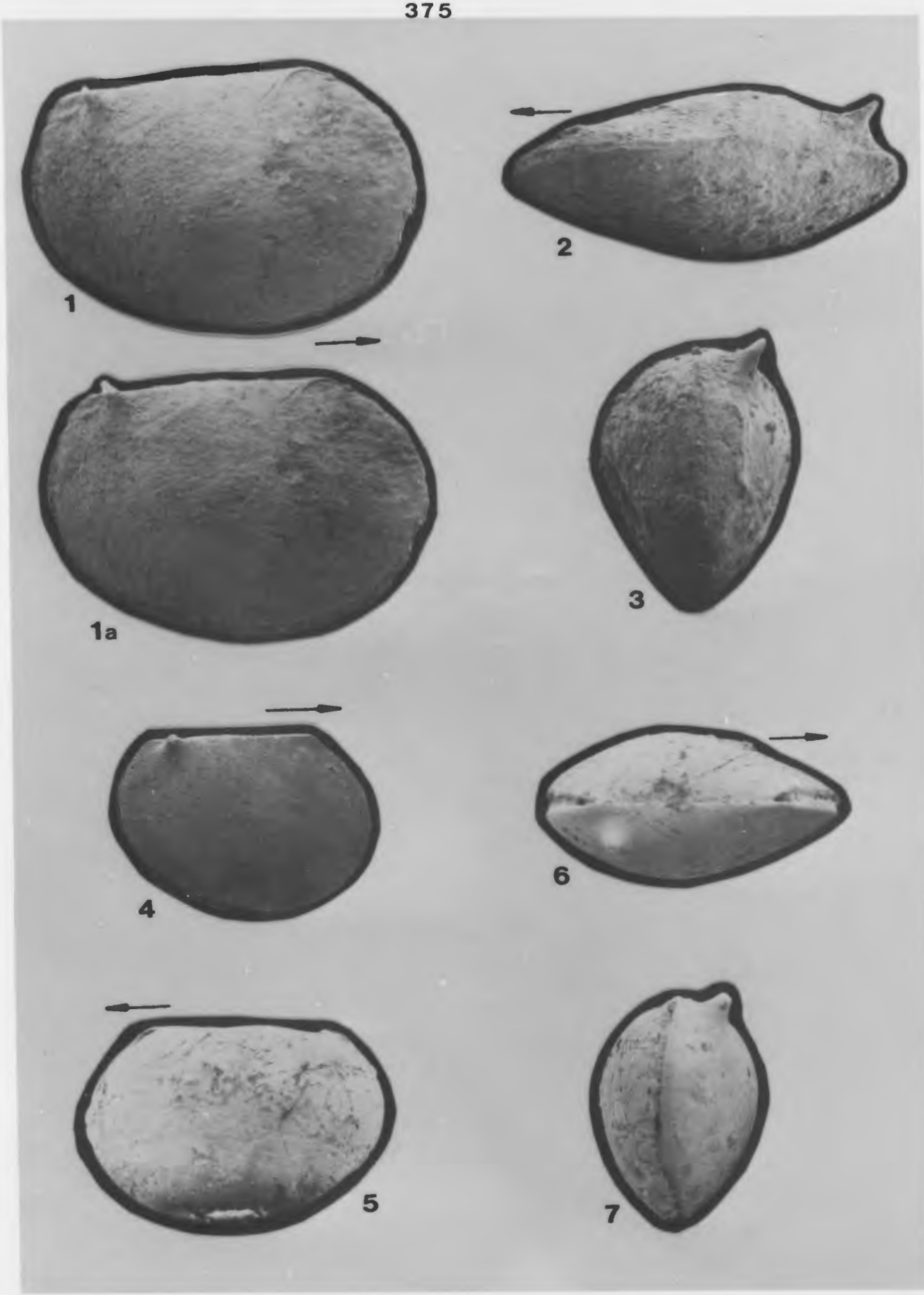

1
2
1a
3
4
6
5
7

PLATE 22

figs. 1 - 3 *Shishaella moreyi*: fig. 1 right aspect; fig. 2, dorsal view; fig. 3, posterior view, magnifications about 35.

figs. 4,5 gen. et sp. indet. 3: fig. 4, left aspect; fig. 5, ventral view, magnification about 130.

figs. 6,7 gen. et sp. indet. 3: fig. 6, dorsal view; fig. 7, ventral view, magnification about 130.

figs. 1 - 3 are a steinkern.

figs. 4 - 7 are steinkerns.

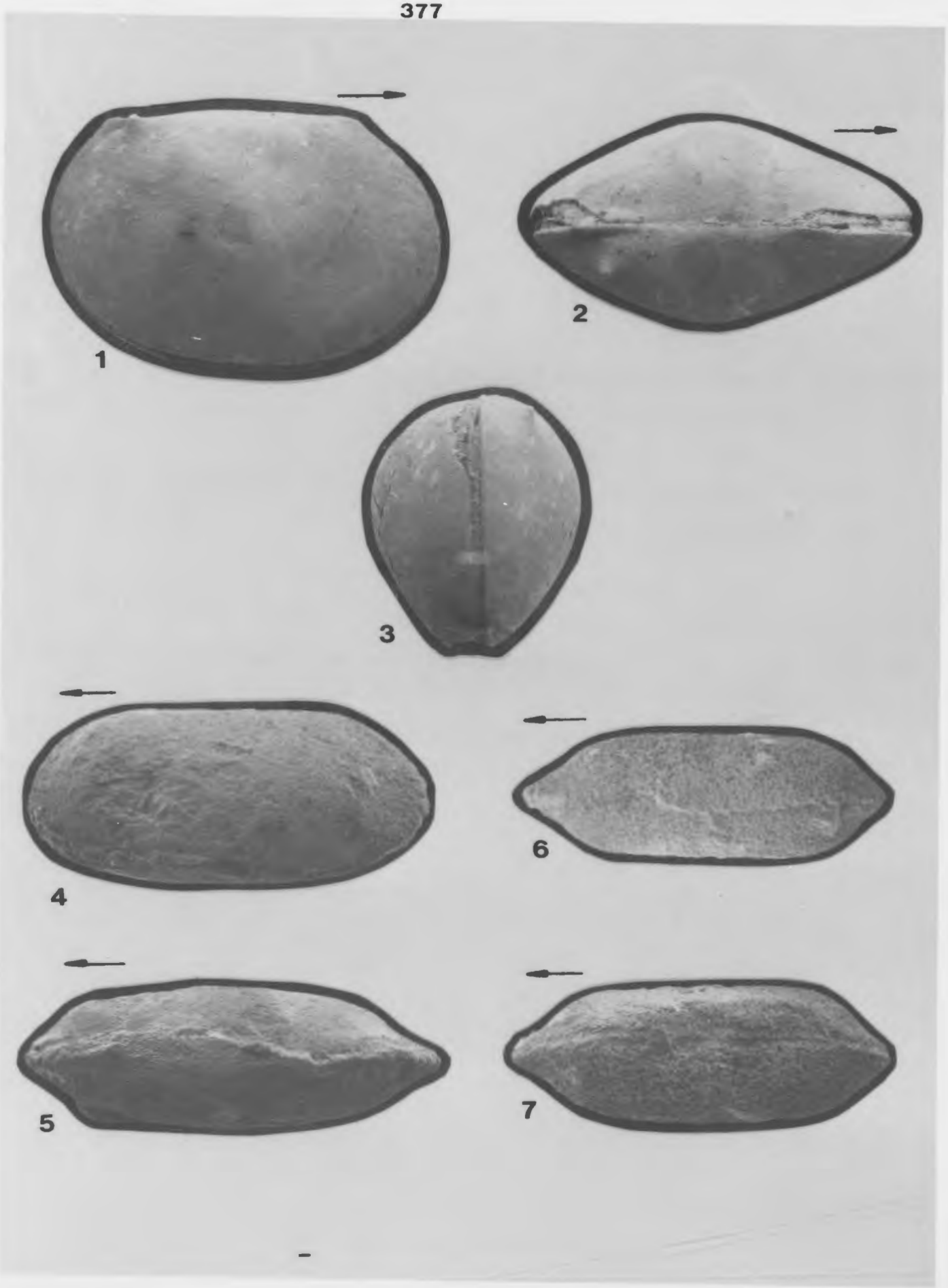

1
2
3
4
5
6
7

PLATE 23

fig. 1 *Polycope* n. sp. A.: right aspect, magnification about 290.

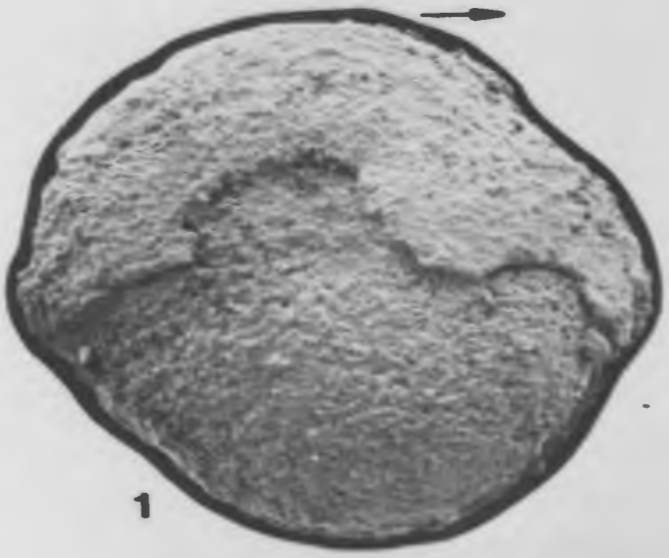
fig. 2 *Polycope* n. sp. A.: left aspect, slightly oblique, magnification about 310.

figs. 3,4 *Polycope* n. sp. A.: fig. 3, left aspect, magnification about 325; fig. 4, enlargement of antero-ventral corner, magnification about 1300.

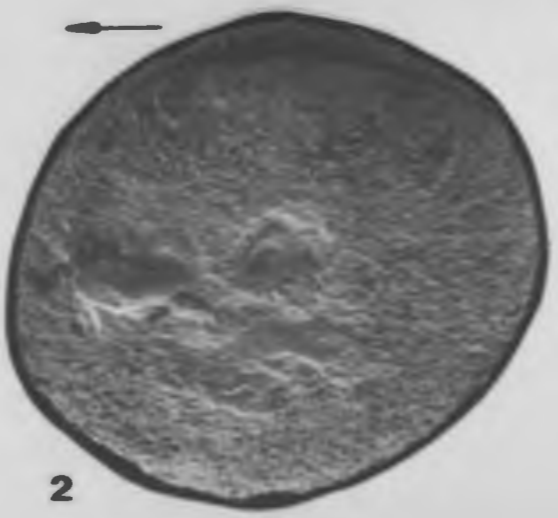
fig.1 is a steinkern with calcite overgrowth.

fig. 2 is a steinkern.

figs. 3,4 is a partially exfoliated carapace.



1



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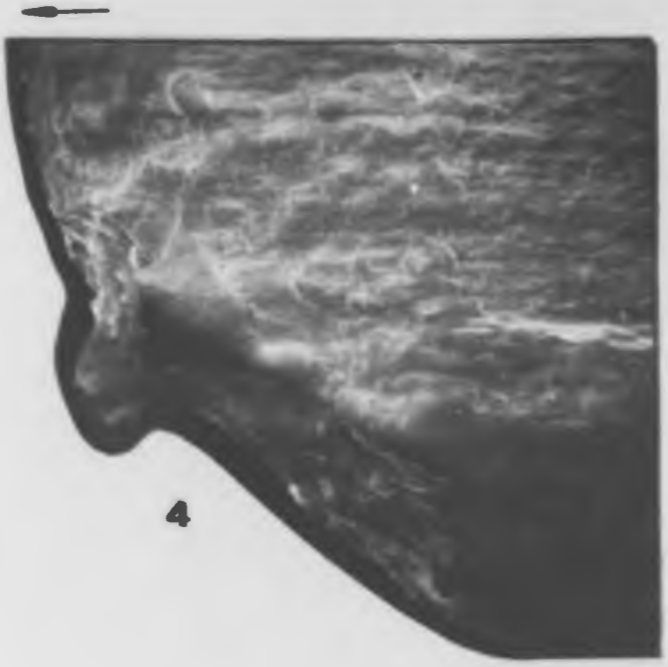

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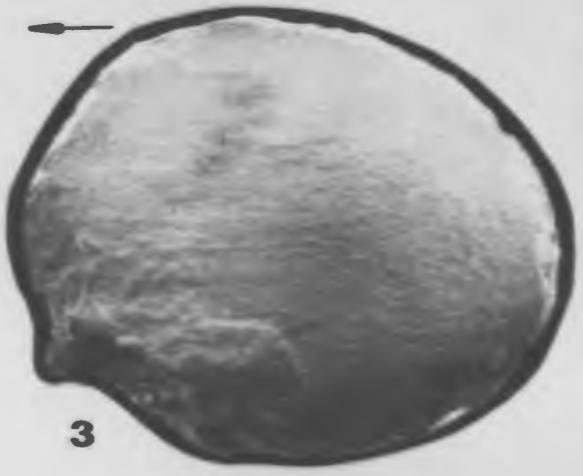


3

PLATE 24

fig. 1 *Tealliocaris* sp. aff. *T. loudonensis*: left aspect of cephalothorax, magnification about 10.

fig. 2 *Tealliocaris* sp. aff. *T. loudonensis*: left aspect of cephalothorax, magnification about 10.

fig. 3 *Tealliocaris* sp. aff. *T. loudonensis*: right aspect of thoracic shield, magnification about 7.5.

figs. 1 - 3 are carapace material.

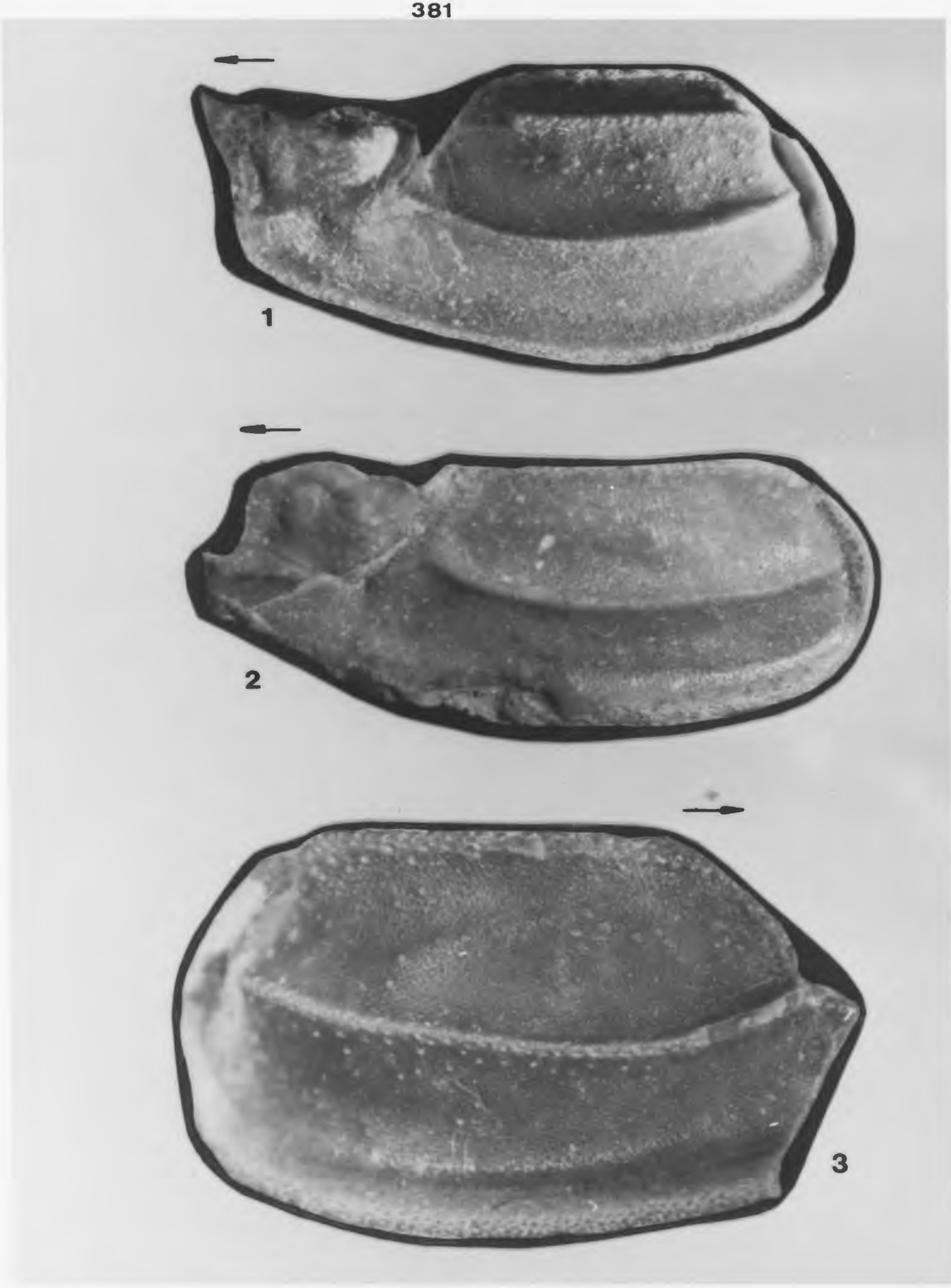

1
2
3

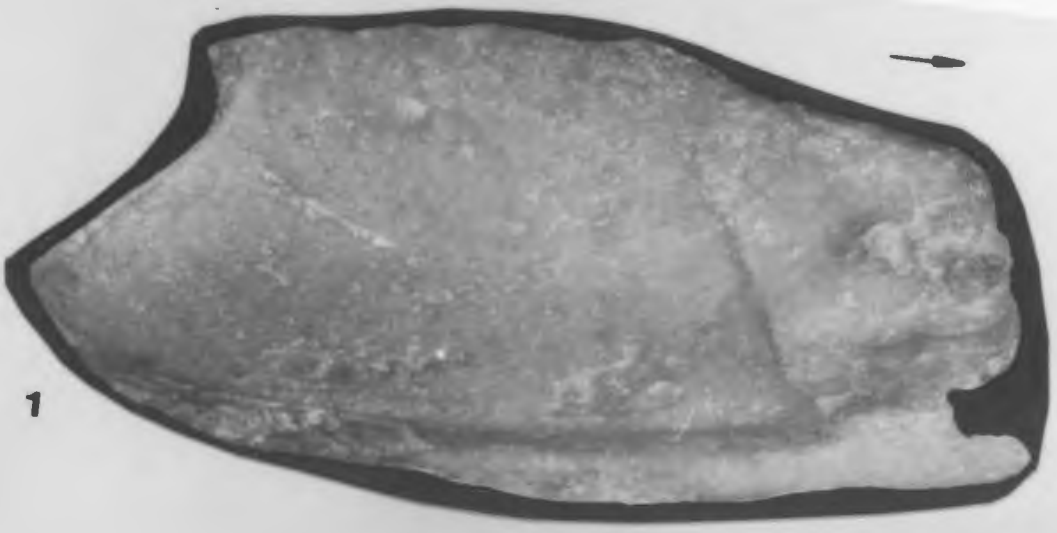
PLATE 25

fig. 1 *Bellocaris newfoundlandensis*: right aspect of cephalothorax, magnification about 5.

fig. 2 *Bellocaris newfoundlandensis*: left aspect of cephalothorax, magnification about 5.

fig. 3 *Bellocaris newfoundlandensis*: dorsal view, magnification about 5.

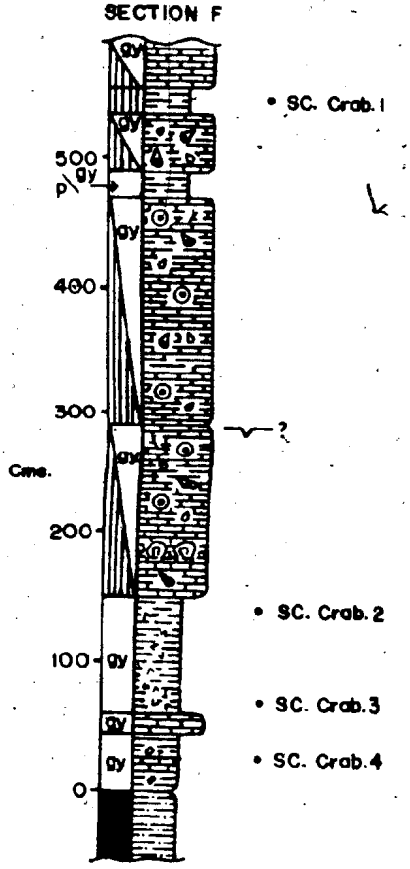
figs. 1 - 3 are carapace material.

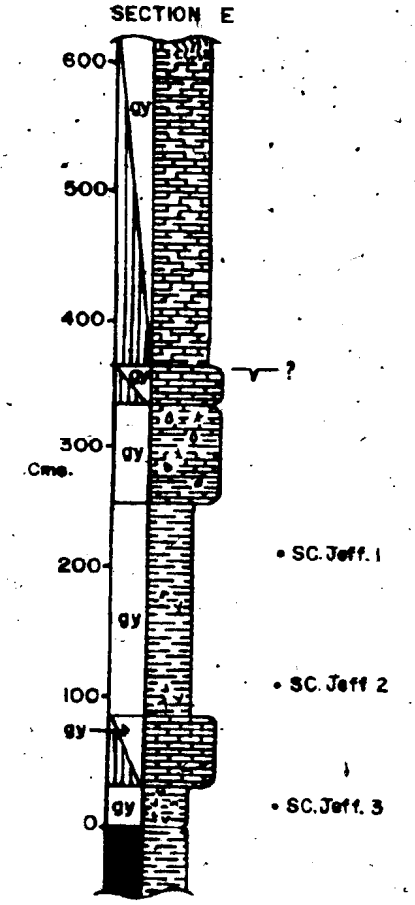


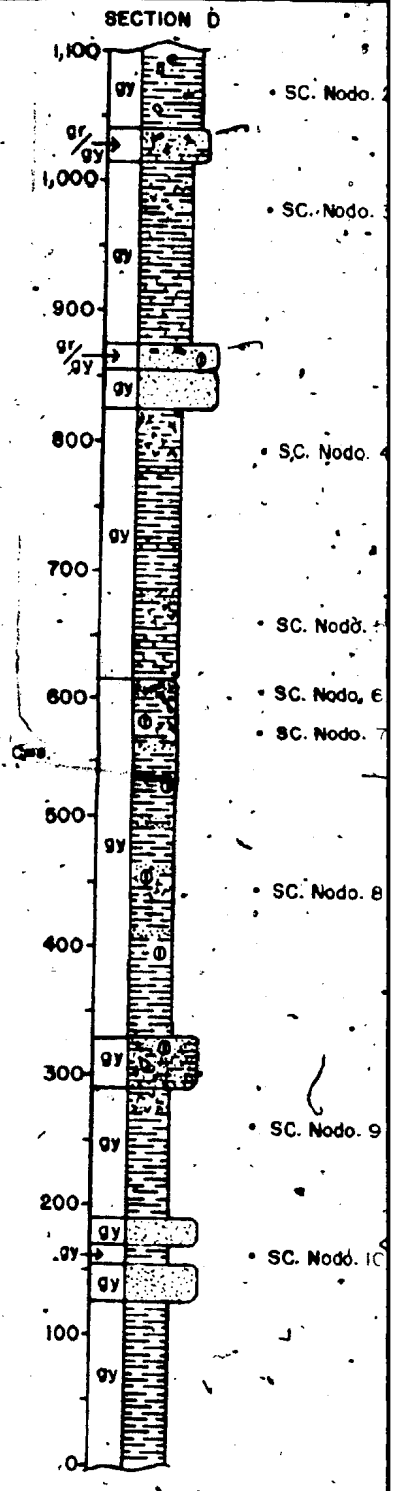
1

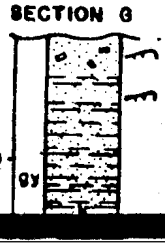
2

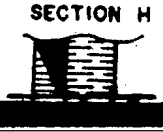
3

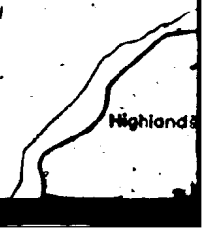

SECTION F
gy
500
p/gy
400
300
Cme.
200
100
0
• SC. Crab. 1
• SC. Crab. 2
• SC. Crab. 3
• SC. Crab. 4
?


SECTION E
600
500
400
300
Cme.
200
100
0
gy
• SC. Jeff. 1
• SC. Jeff 2
• SC. Jeff. 3
?

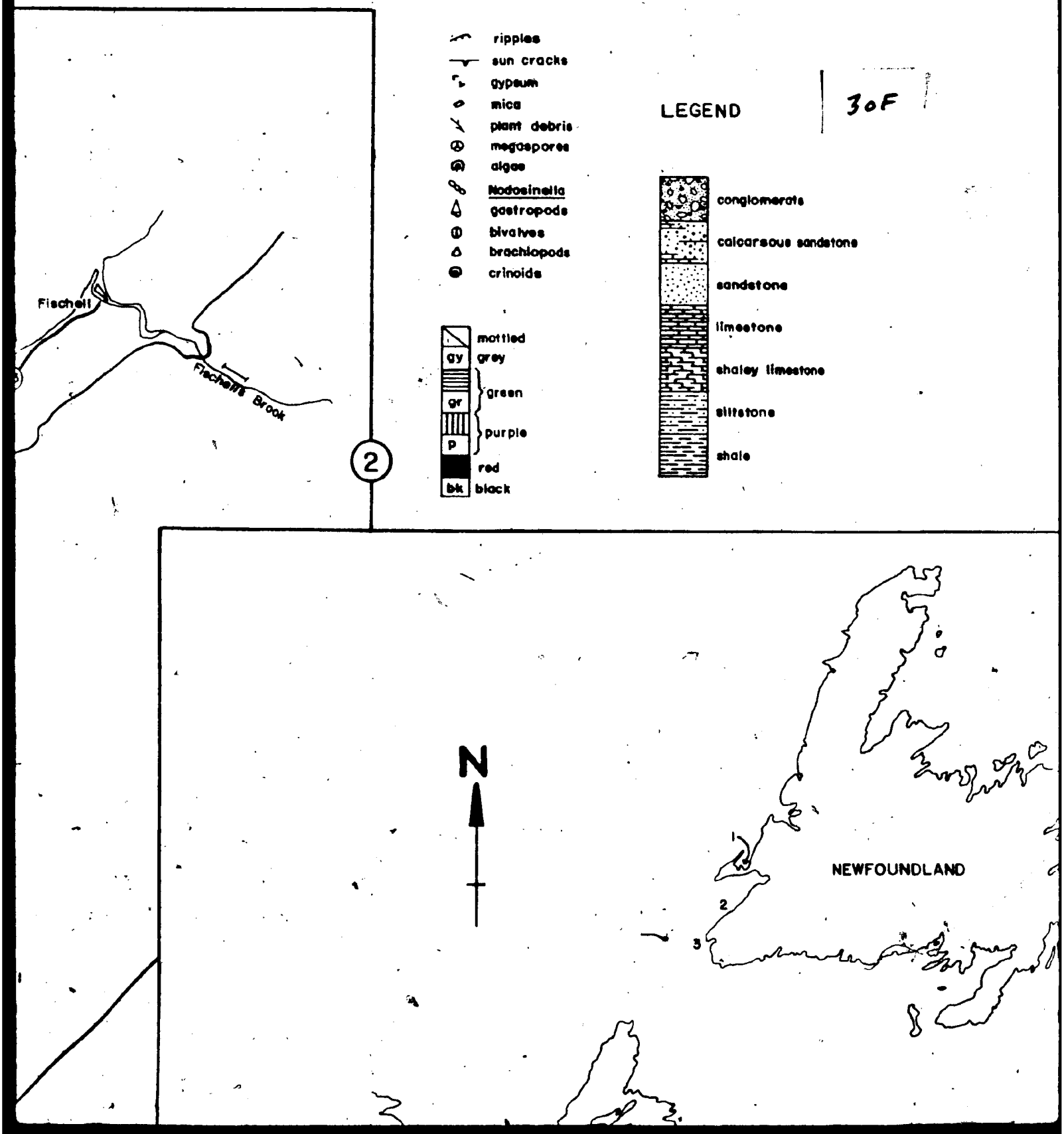

SECTION D
1,100
1,000
900
800
700
600
500
400
300
200
100
0
gy
gr/gy
Cme.
• SC. Nodo. 2
• SC. Nodo. 3
• S.C. Nodo. 4
• SC. Nodo. 5
• SC. Nodo. 6
• SC. Nodo. 7
• SC. Nodo. 8
• SC. Nodo. 9
• SC. Nodo. 10

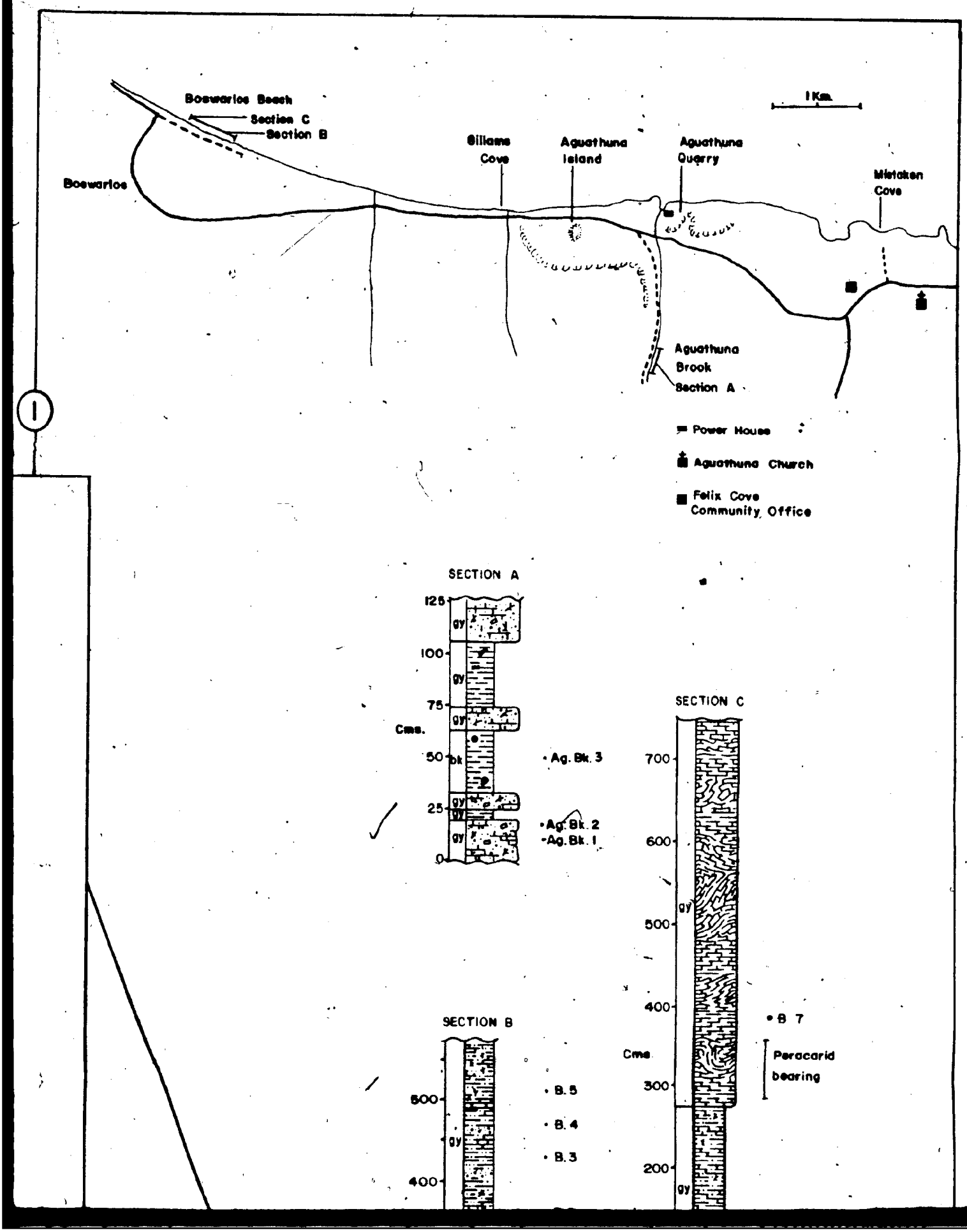

SECTION G
900
gy

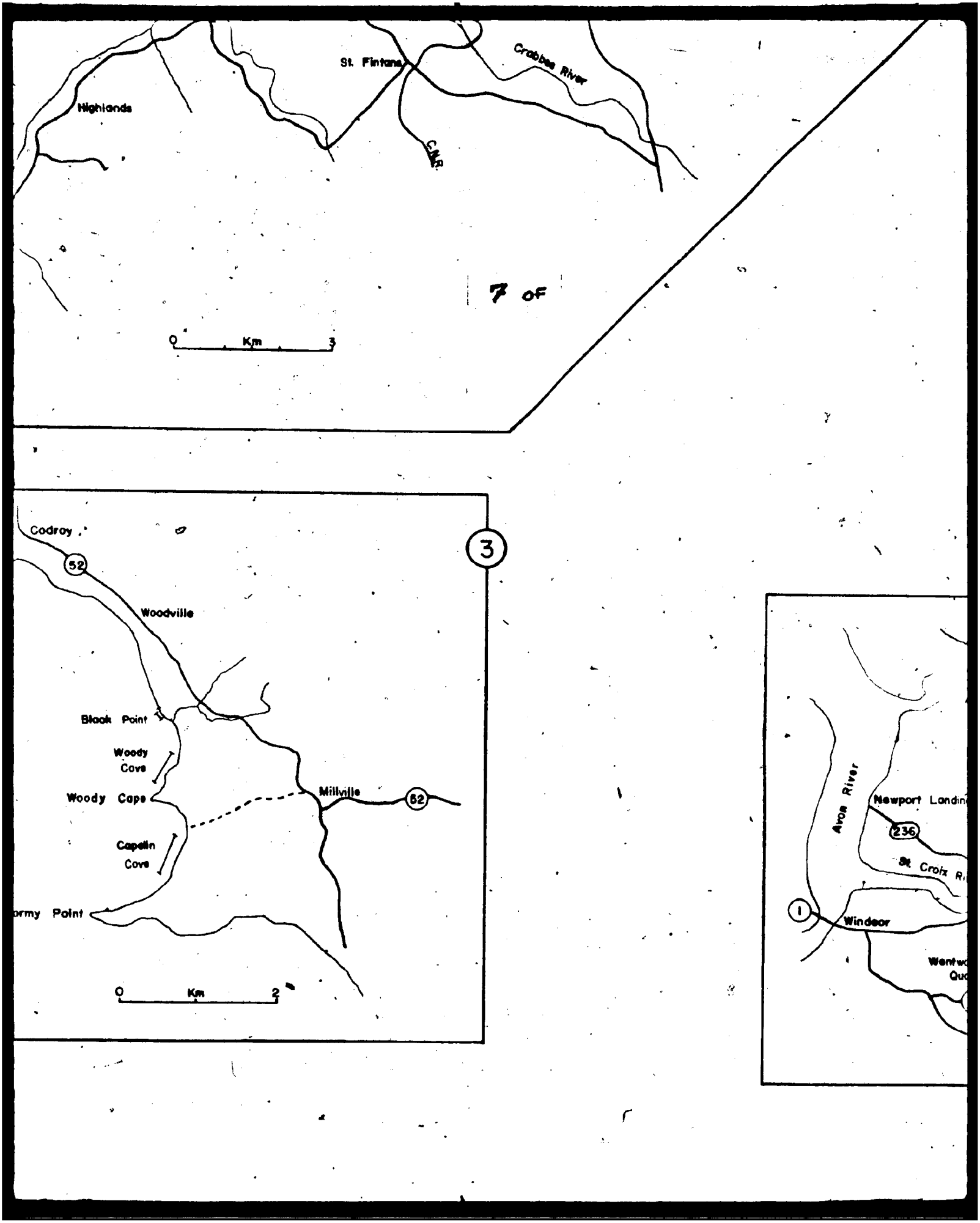

SECTION H

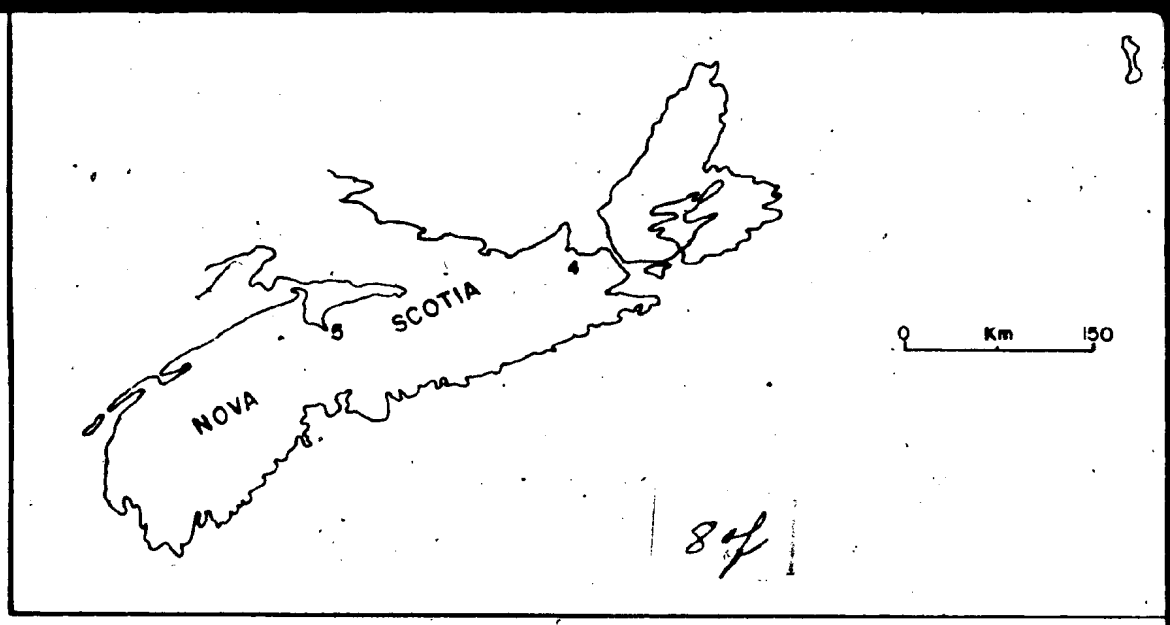

Highlands

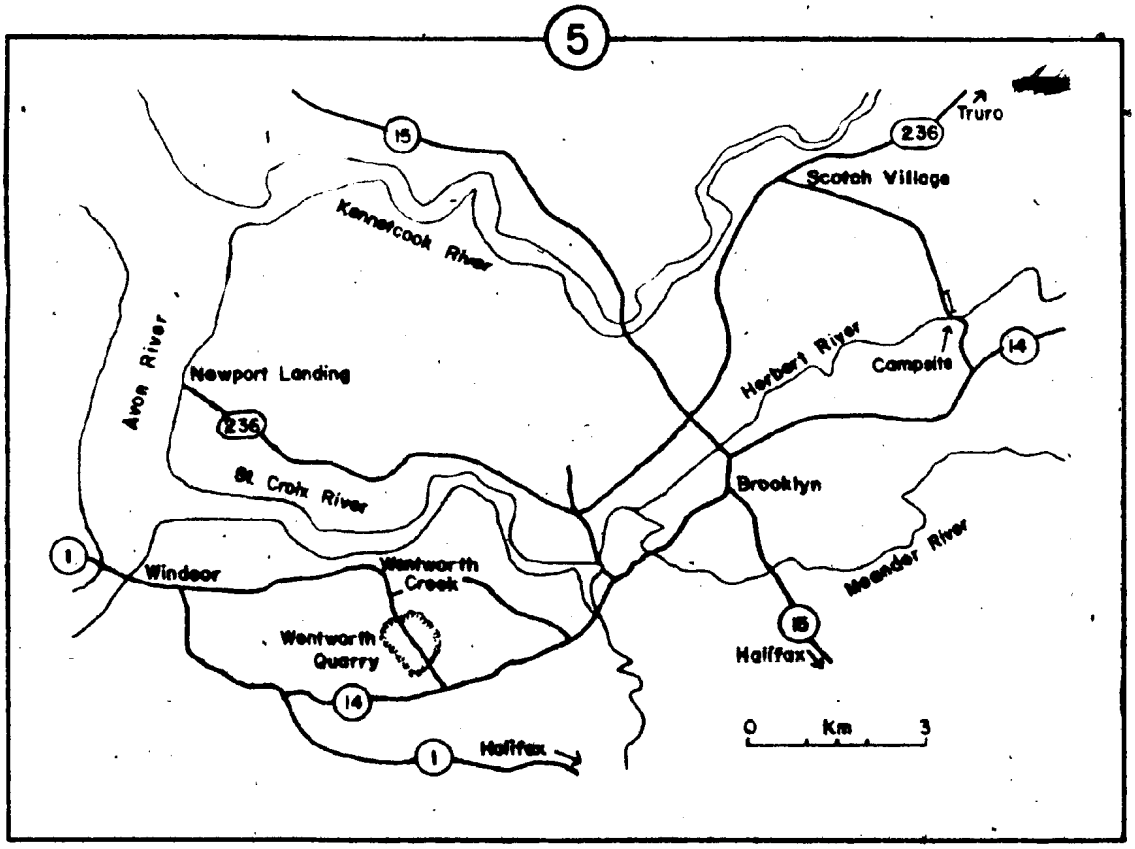
TEXT FIGURE 2·1 LOCALITY MAP

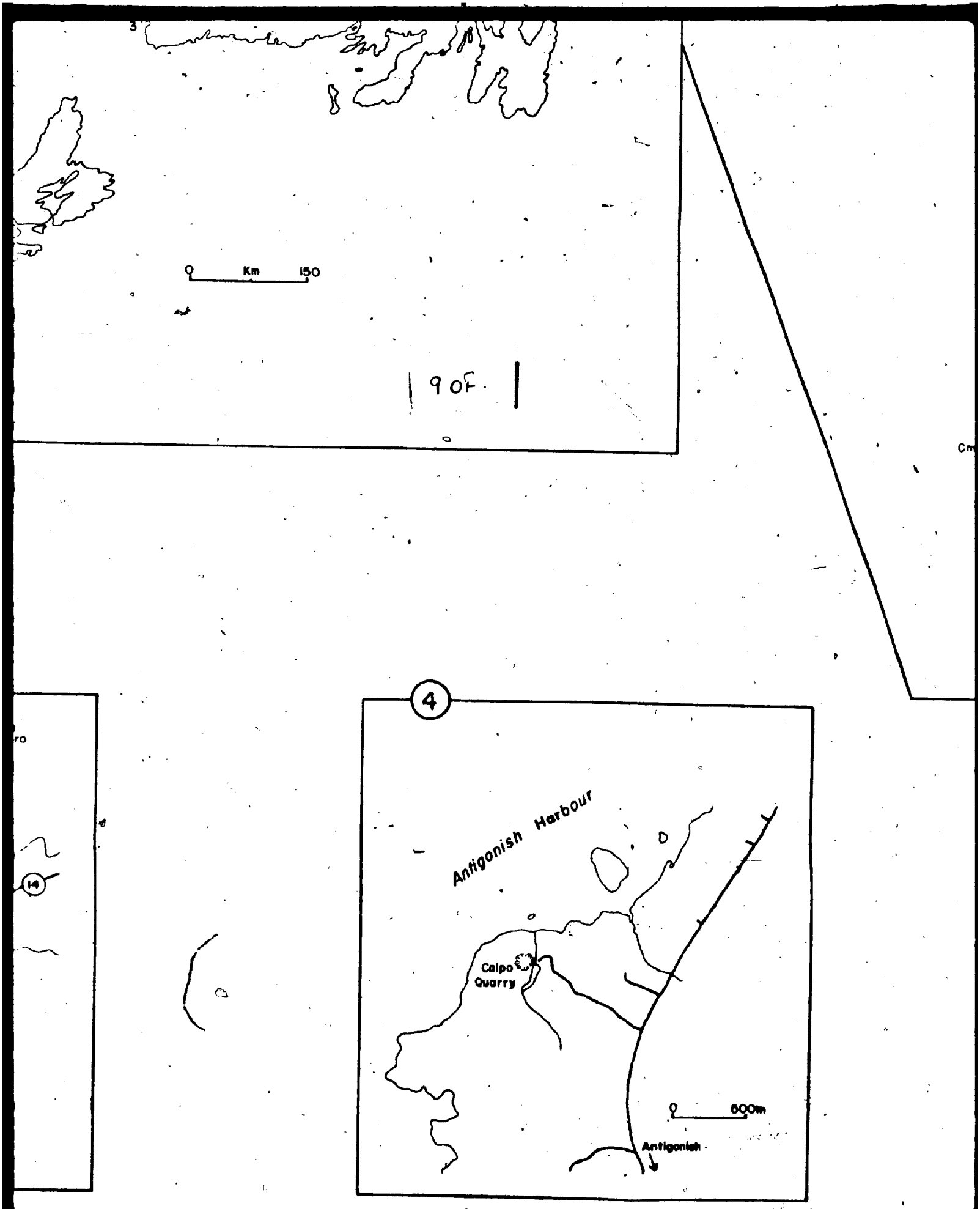


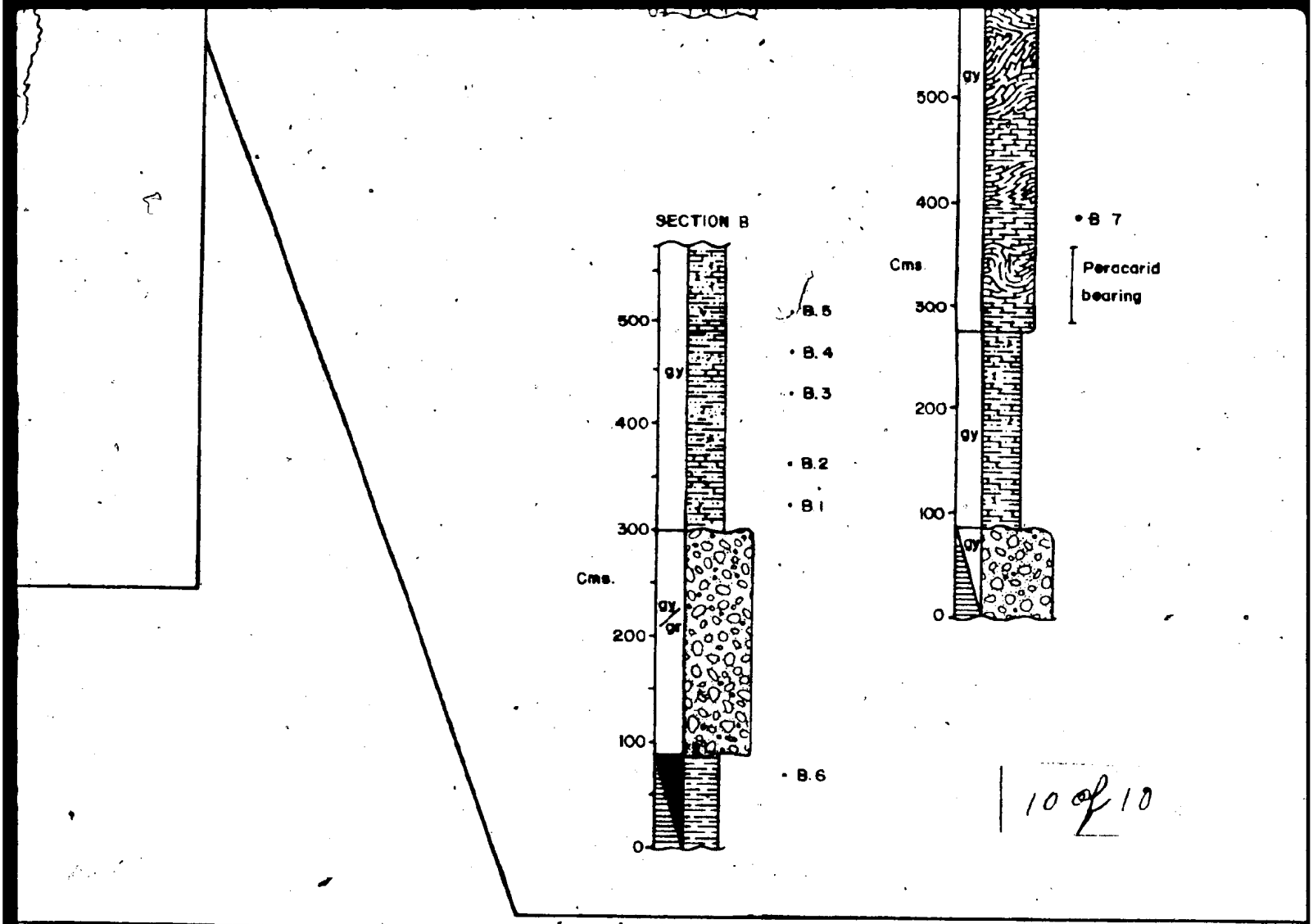

Boswarlos Beach
Section C
Section B
Boswarlos
Silliams Cove
Aguathuna Island
Aguathuna Quarry
Mistaken Cove
1Km.
Aguathuna Brook Section A
Power House
Aguathuna Church
Felix Cove Community Office
SECTION A
125
100
75
Cms.
50
25
0
gy
bk
Ag. Bk. 3
Ag. Bk. 2
Ag. Bk. 1
SECTION C
700
600
500
400
300
200
B 7
Peracarid bearing
SECTION B
500
400
B. 5
B. 4
B. 3


Highlands
St. Fintans
Crabbes River
7 OF
0 Km 3
Codroy
52
Woodville
3
Black Point
Woody Cove
Woody Cape
Millville
52
Capelin Cove
ormy Point
0 Km 2
Avon River
Newport Landin
236
St. Croix R
1
Windsor
Wentw
Que

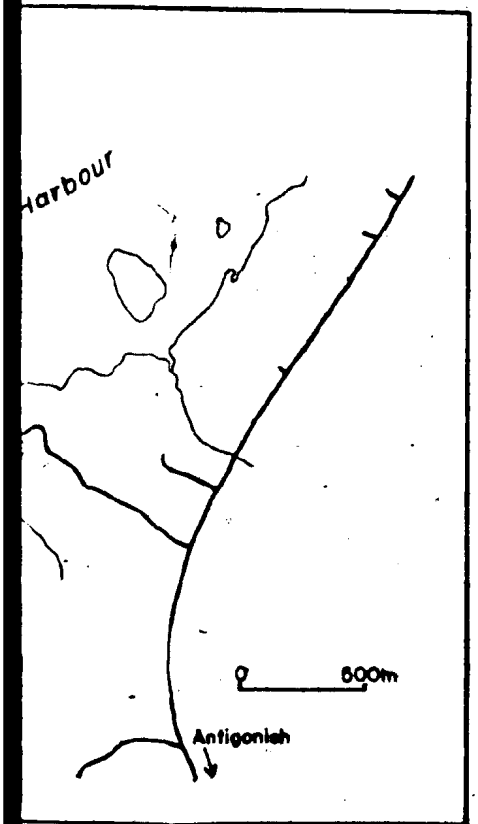

NOVA
SCOTIA
0 Km 150


5
15
236
Truro
Scotch Village
Kennetcook River
Avon River
Newport Landing
236
St Croix River
Herbert River
Campsite
14
Brooklyn
1
Windsor
Wentworth Creek
Wentworth Quarry
14
1
Halifax
Meander River
18
Halifax
0 Km 3

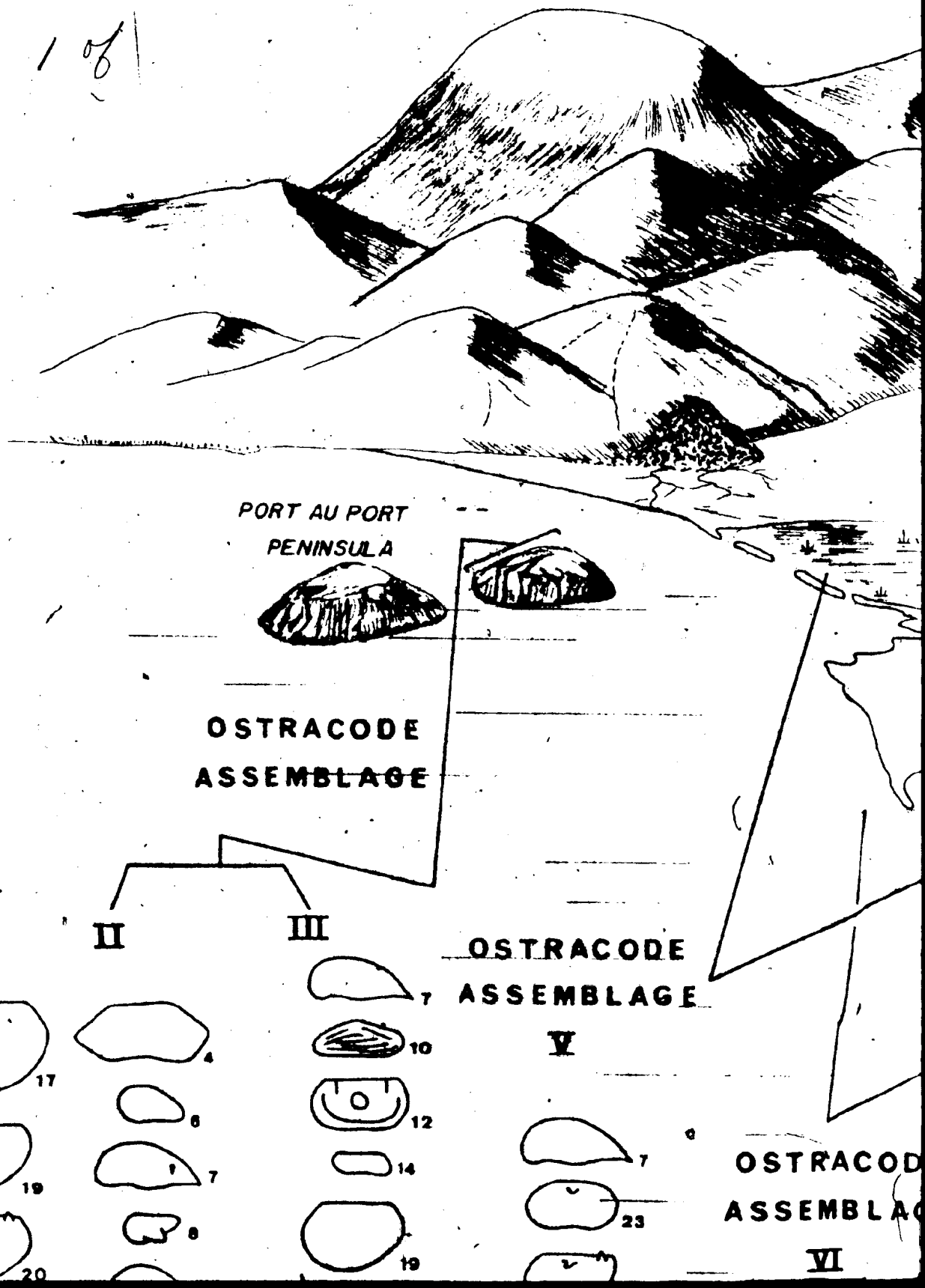

Km 150
190F.
4
Antigonish Harbour
Calpo Quarry
500m
Antigonish

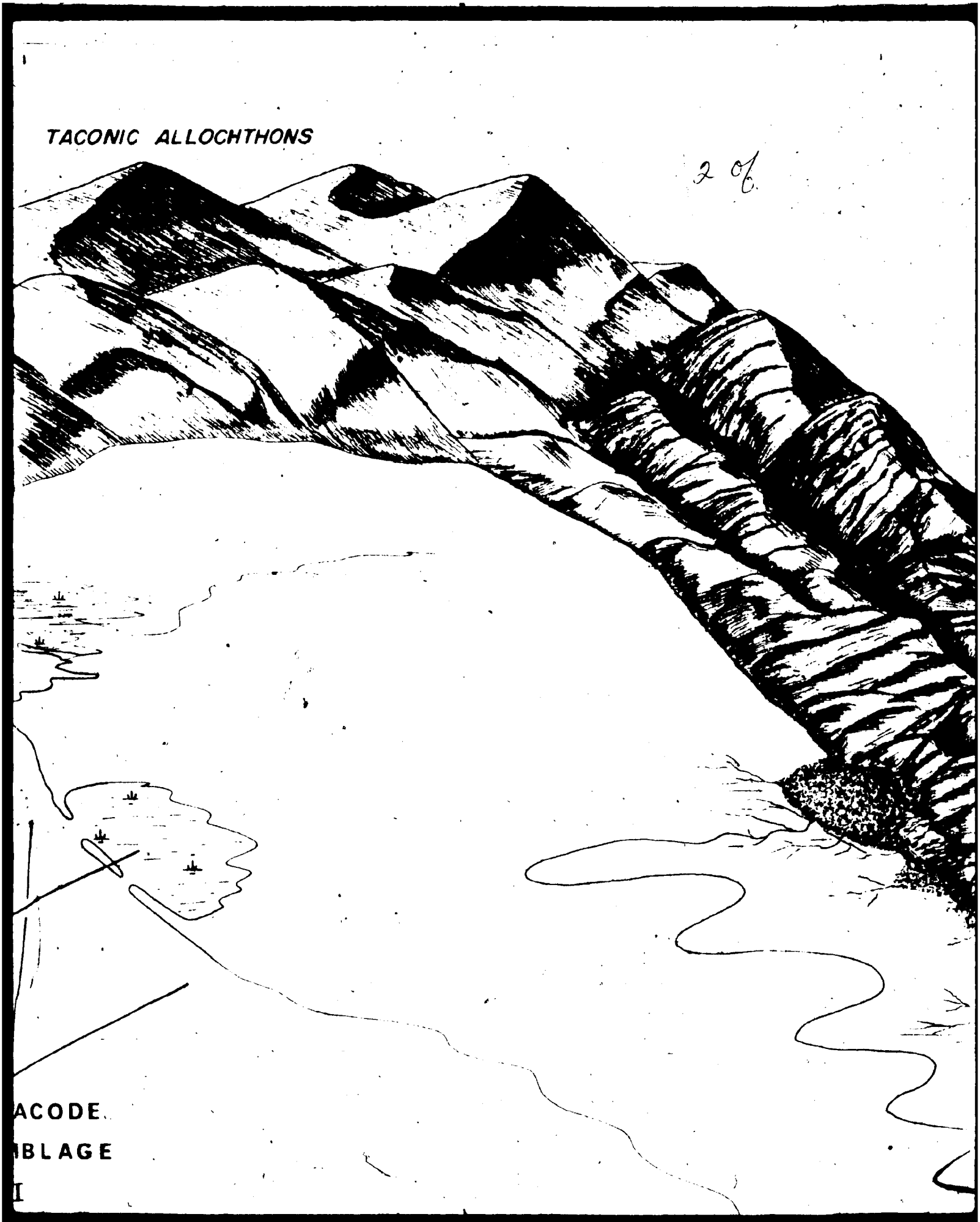


10 of 10

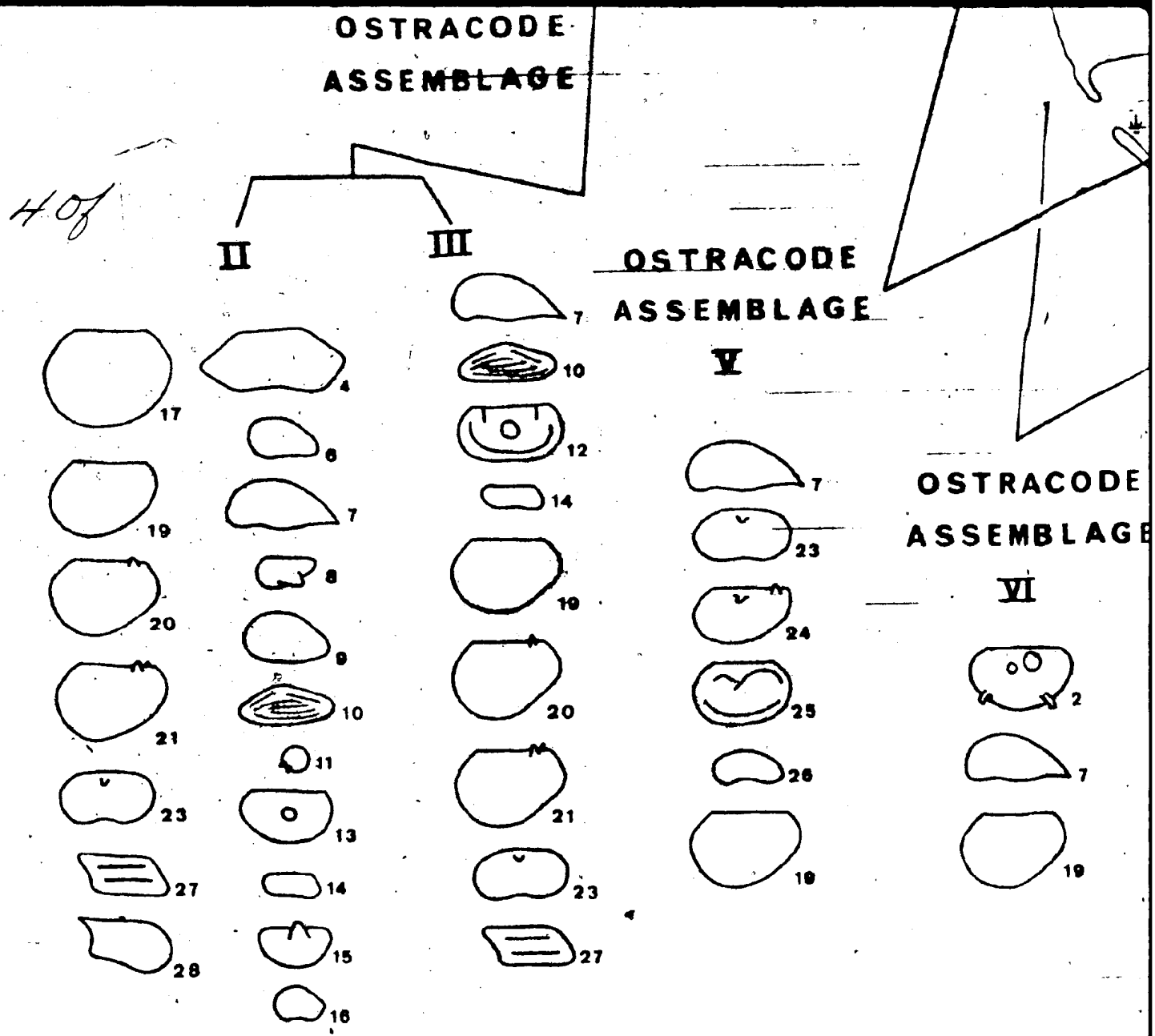


LOCALITY REFERENCES:	MAP AREA:
Brown & Knight, 1975	– 3
Dix, 1981	– 1
Fong, 1975	– 2
Geldsetzer et al., 1980	– 4, 5
Knight & Fong, 1975	– 2


PORT AU PORT
PENINSULA
OSTRACODE
ASSEMBLAGE
II
III
OSTRACODE
ASSEMBLAGE
V
OSTRACOD
ASSEMBLA
VI
17
4
6
19
7
8
20
7
10
12
14
19
7
23

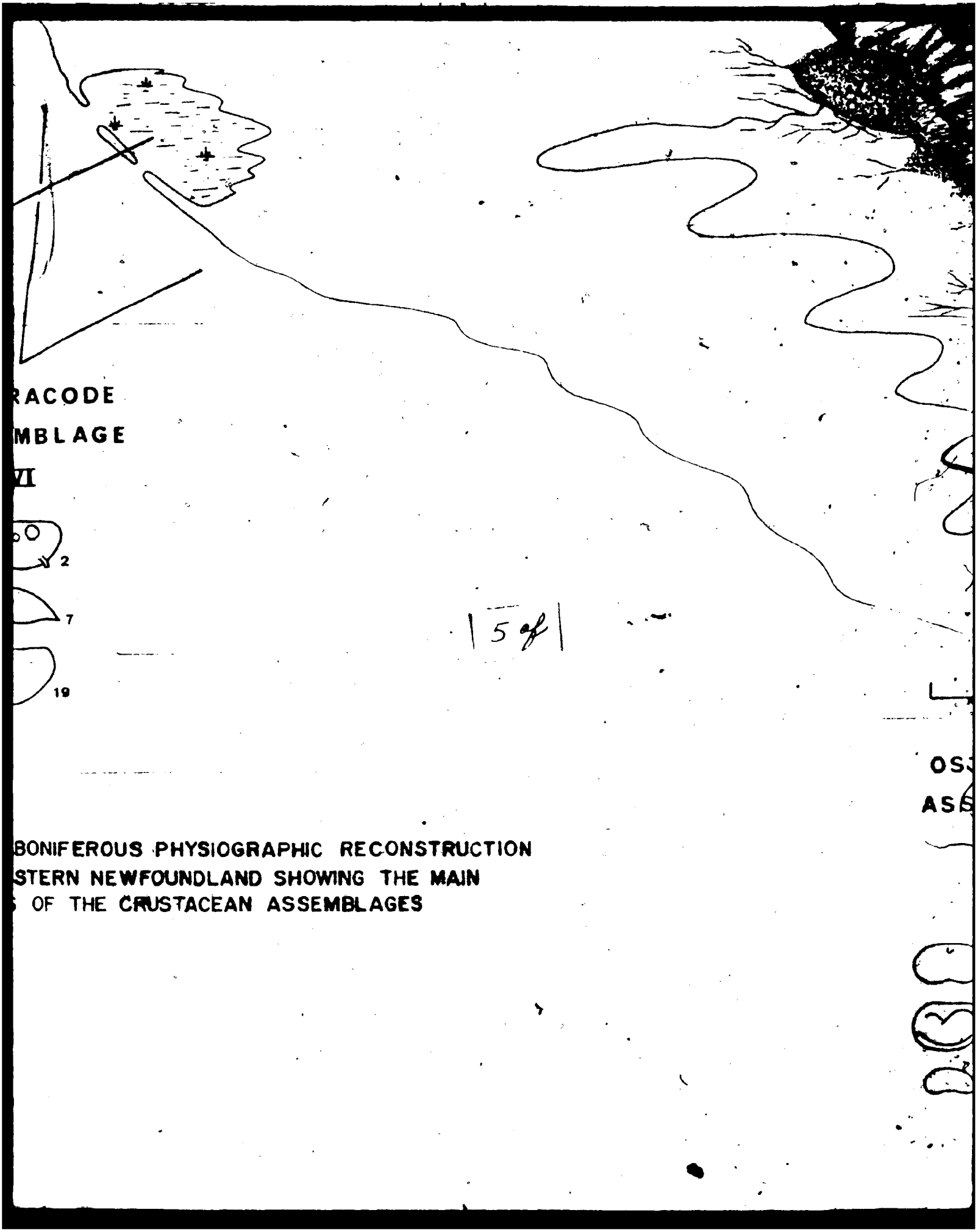

TACONIC ALLOCHTHONS
2 %
ACODE
BLAGE
I


LONG RANGE BASEMENT HIGH



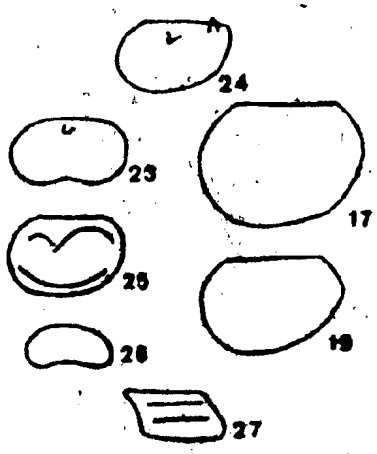
KEY TO NUMBERS: TEXT-FIG 4-15

TEXT-FIG. 5-1 MIDDLE CARBONIFERO
OF SOUTHWESTERN NE
COMPONENTS OF THE



BONIFEROUS PHYSIOGRAPHIC RECONSTRUCTION
STERN NEWFOUNDLAND SHOWING THE MAIN
S OF THE CRUSTACEAN ASSEMBLAGES

OSTRACODE
ASSEMBLAGE
VII

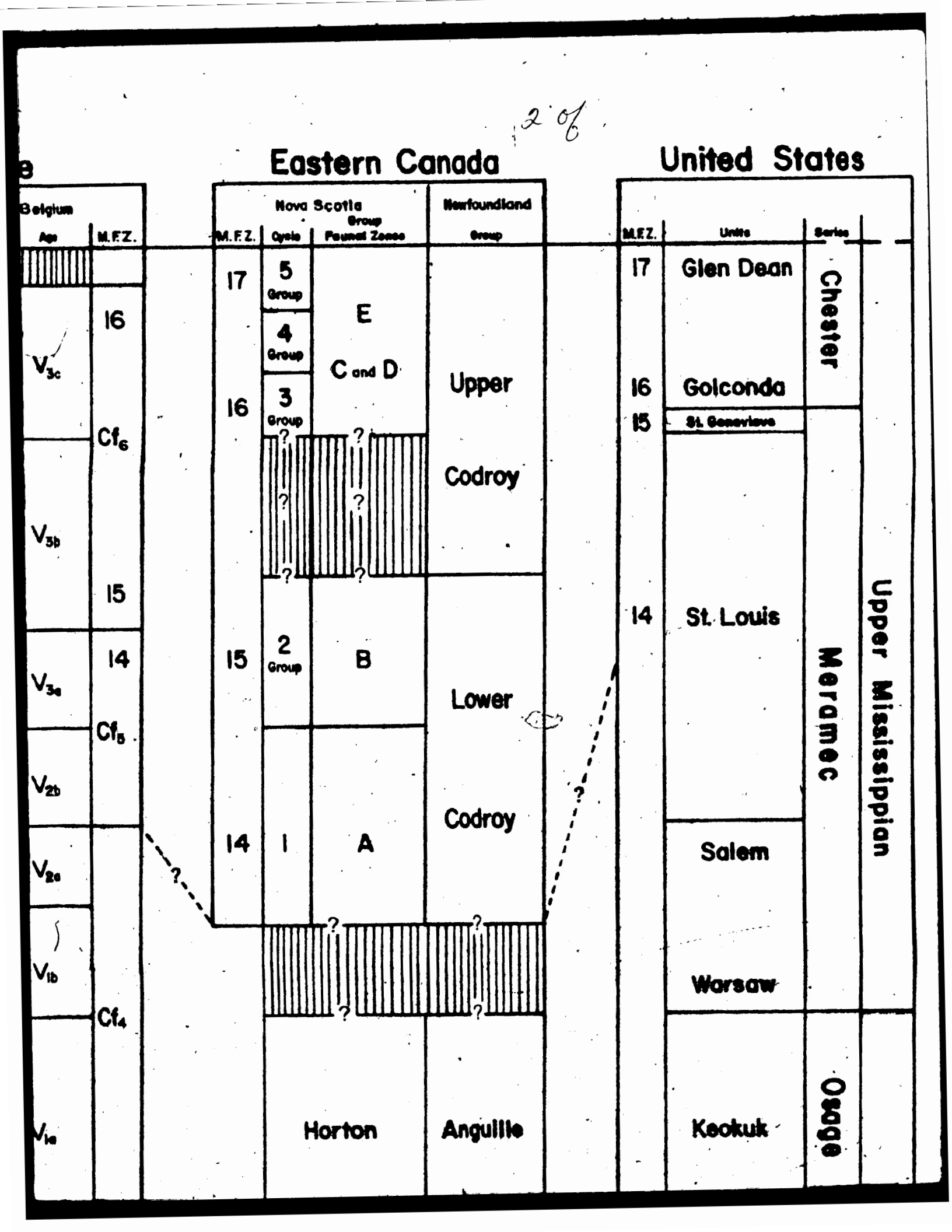


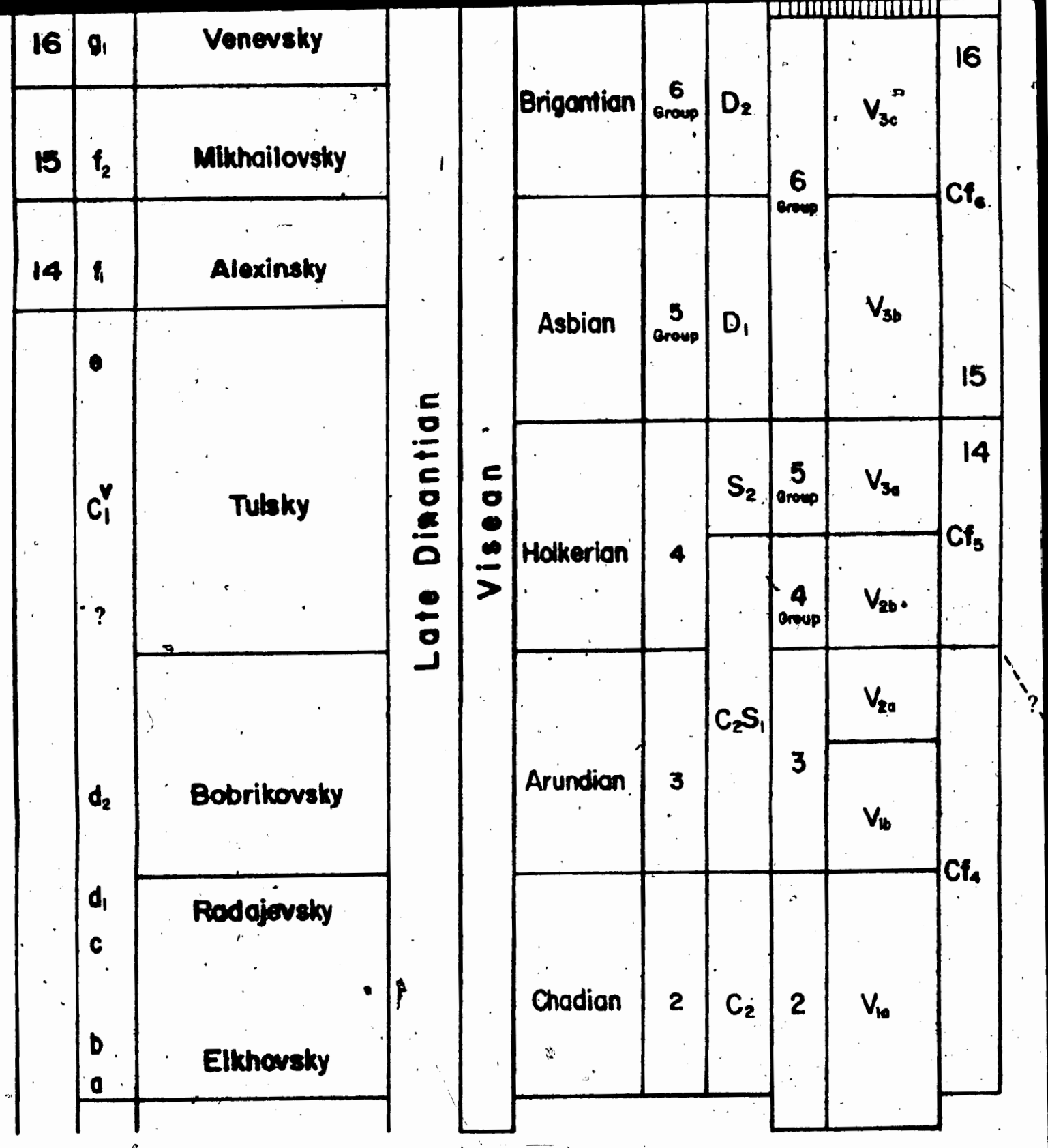
1 of

Russia

Western Europe

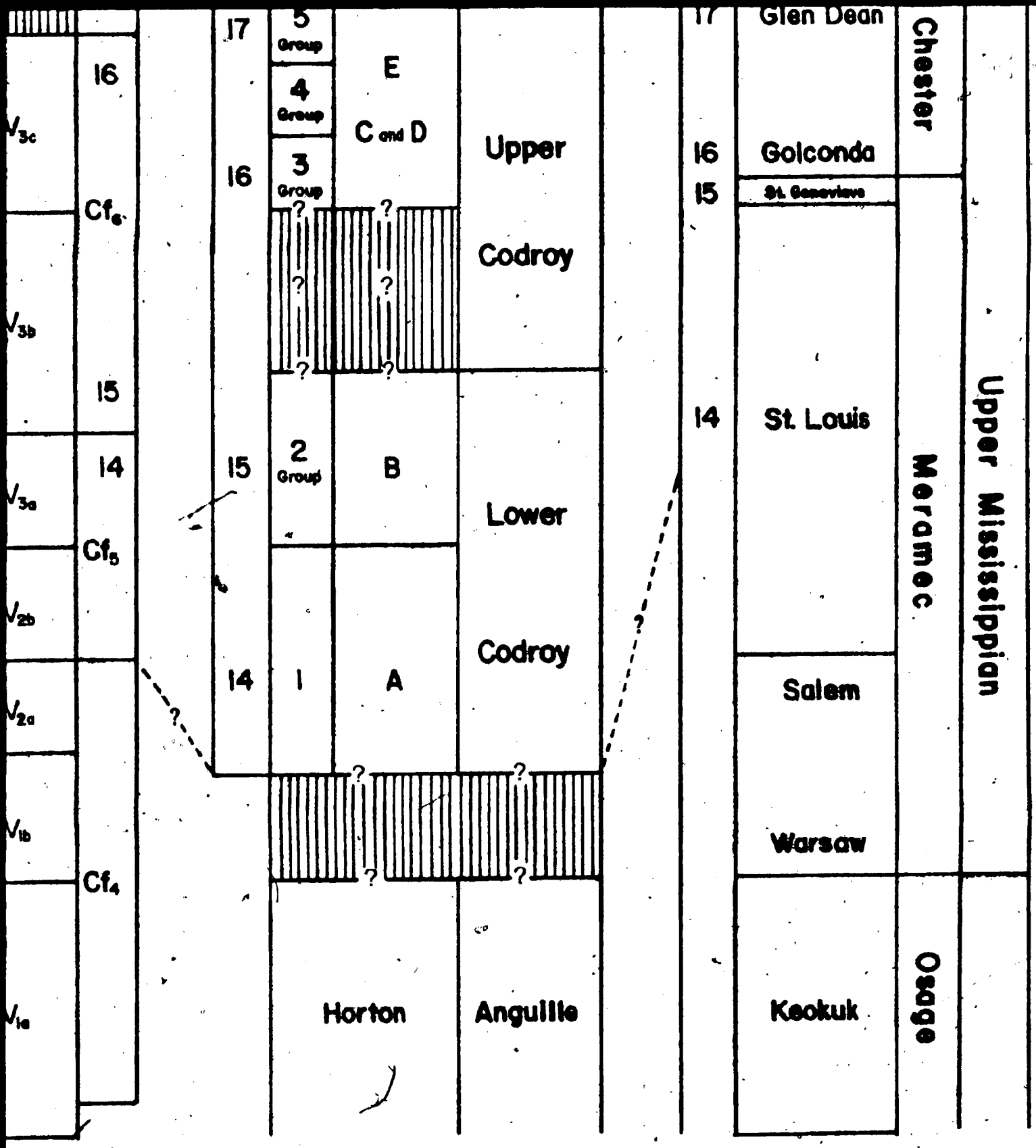
M.F.Z.	Donets Zone	Platform Horizon	Series	England Stage	England Cycle	England Megafaunal	Belgium Cycle	Belgium Age	Belgium M.F.Z.
16	g_1	Venevsky	Late Dinantian / Visean	Brigantian	6 Group	D_2	6 Group	V_{3c}	16
15	f_2	Mikhailovsky							Cf_6
14	f_1	Alexinsky		Asbian	5 Group	D_1		V_{3b}	15
	e	Tulsky		Holkerian	4	S_2	5 Group	V_{3a}	14
	C_1^V								Cf_5
	?					—	4 Group	V_{2b}	
	d_2	Bobrikovsky		Arundian	3	C_2S_1	3	V_{2a}	?
								V_{1b}	Cf_4
	d_1 c	Radajevsky		Chadian	2	C_2	2	V_{1a}	
	b a	Elkhovsky							


Eastern Canada
United States
Belgium
Age
M.F.Z.
Nova Scotia
M.F.Z.
Cycle
Group
Faunal Zones
Newfoundland
Group
M.F.Z.
Units
Series
17
16
15
14
V_{3c}
V_{3b}
V_{3a}
V_{2b}
V_{2a}
V_{1b}
V_{1a}
Cf_6
Cf_5
Cf_4
5 Group
4 Group
3 Group
2 Group
1
E
C and D
B
A
Upper
Codroy
Lower
Codroy
Horton
Anguille
Glen Dean
Golconda
St. Genevieve
St. Louis
Salem
Warsaw
Keokuk
Chester
Meramec
Osage
Upper Mississippian



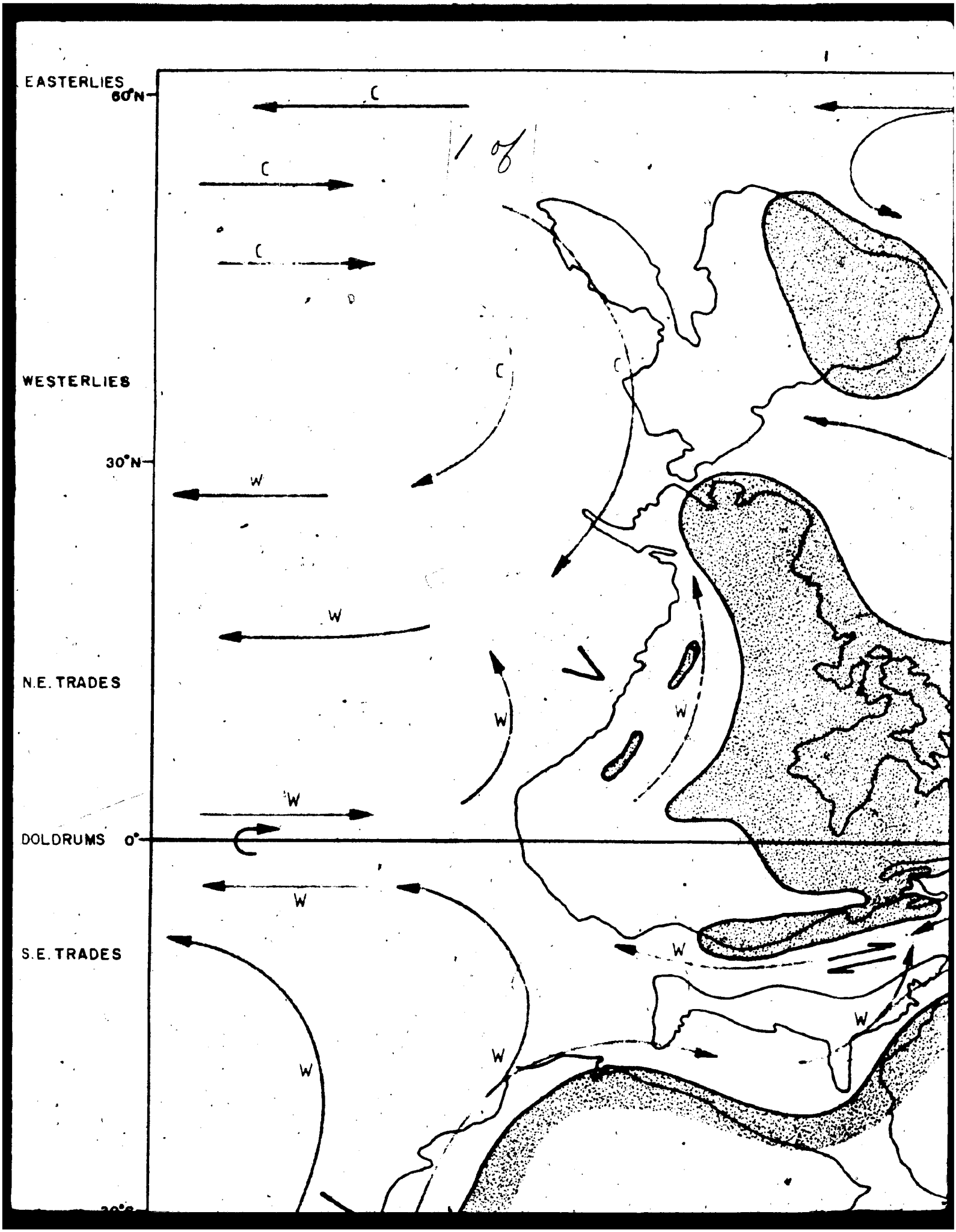
M.F.Z. = Mamet Forem Zone

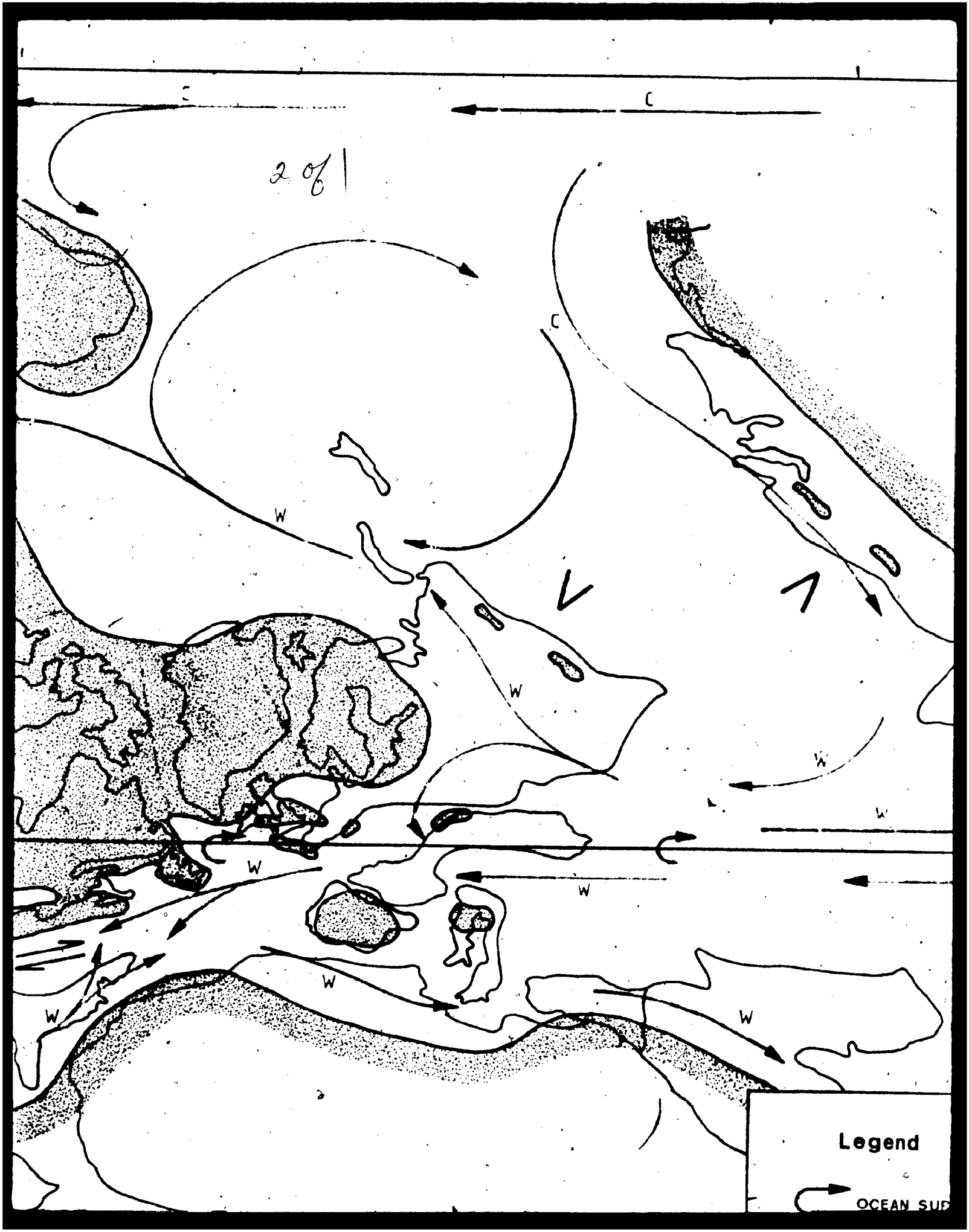
TEXT FIGURE 1·7 MIDDLE CARBONIFER



BONIFEROUS CORRELATION CHART

4084


EASTERLIES
60°N
C
C
C
C
C
WESTERLIES
30°N
W
W
N.E. TRADES
W
W
W
DOLDRUMS
0°
W
S.E. TRADES
W
W
W
W
W
20°S


C
C
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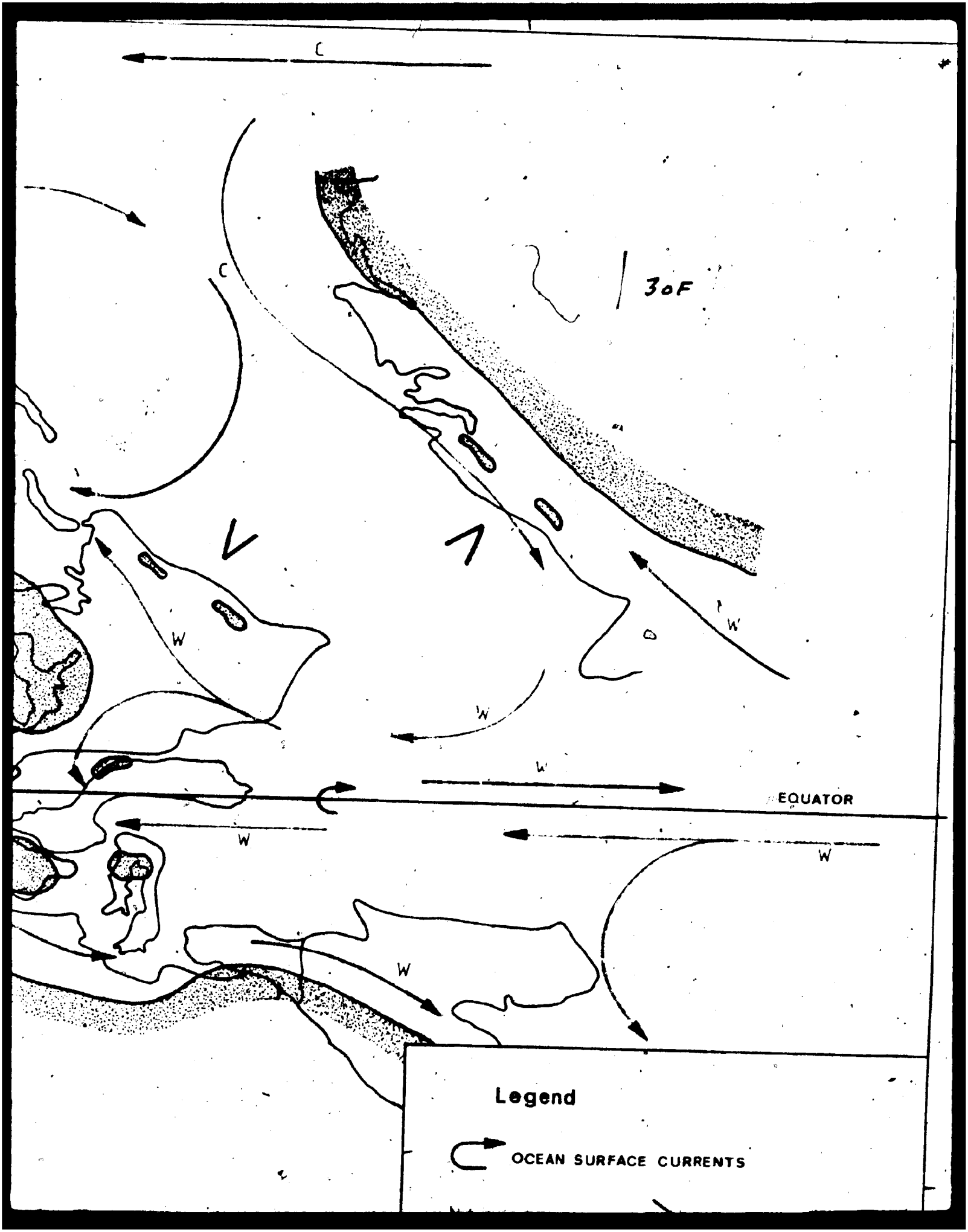
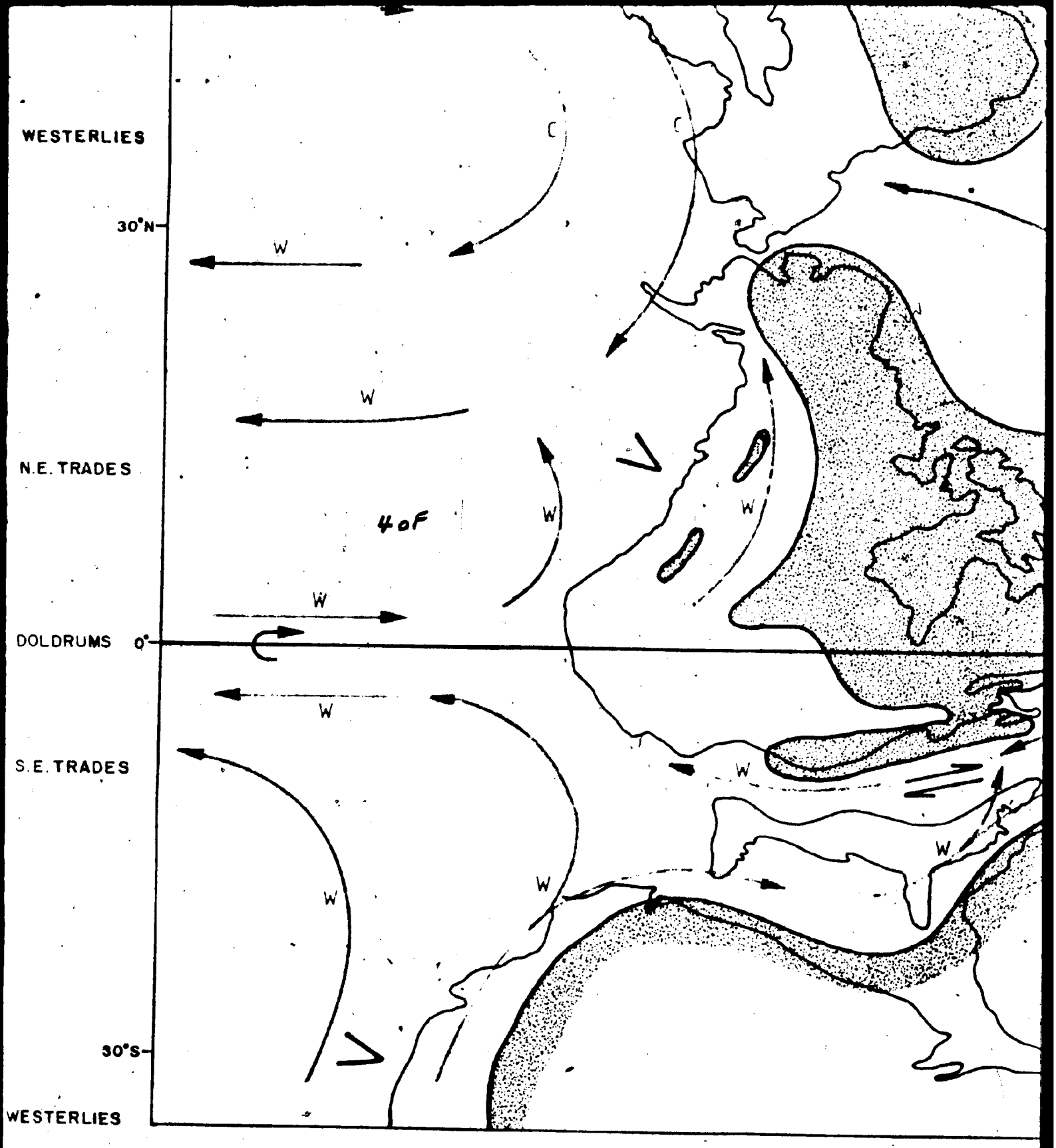
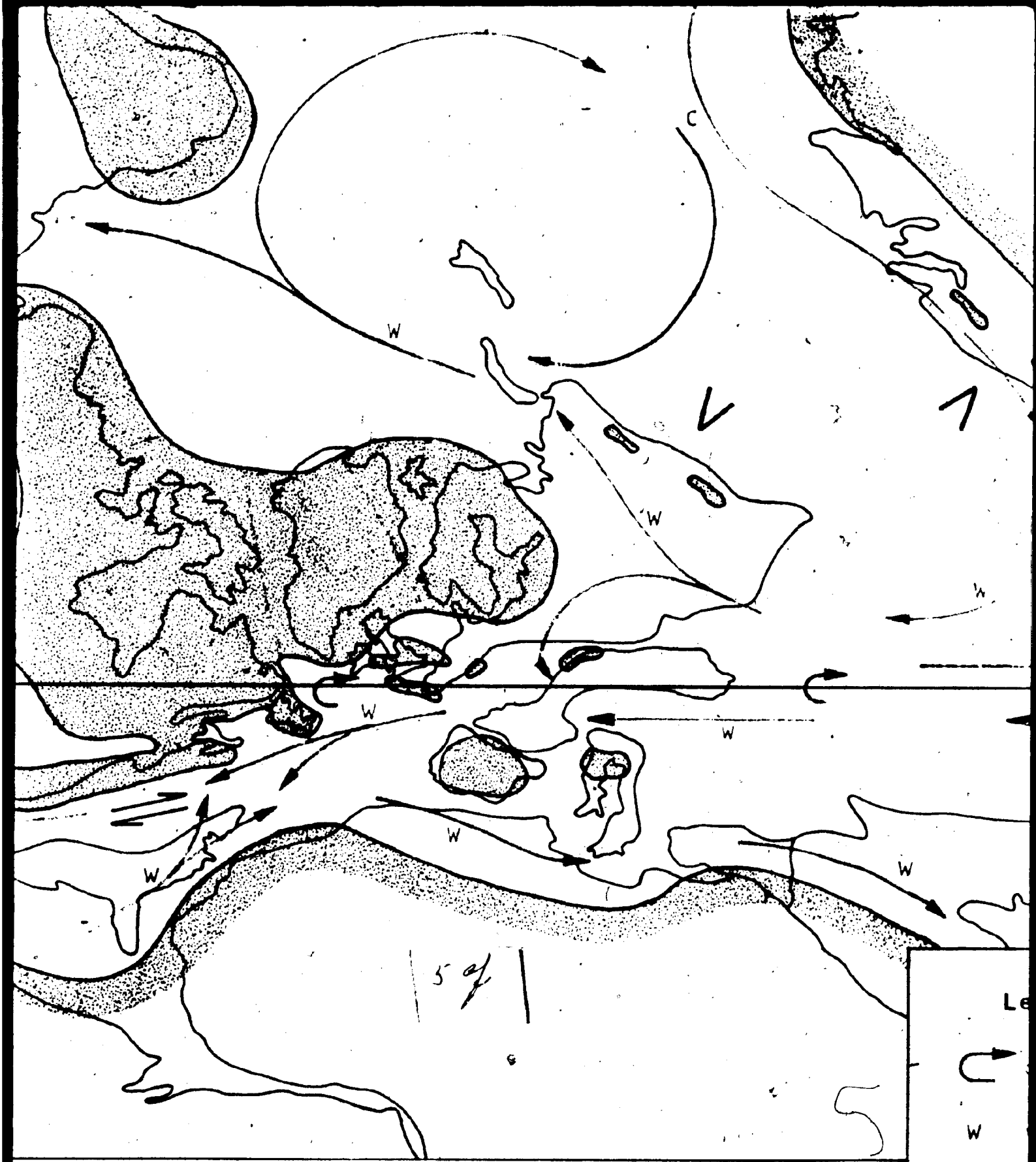
W
Legend
OCEAN SUR

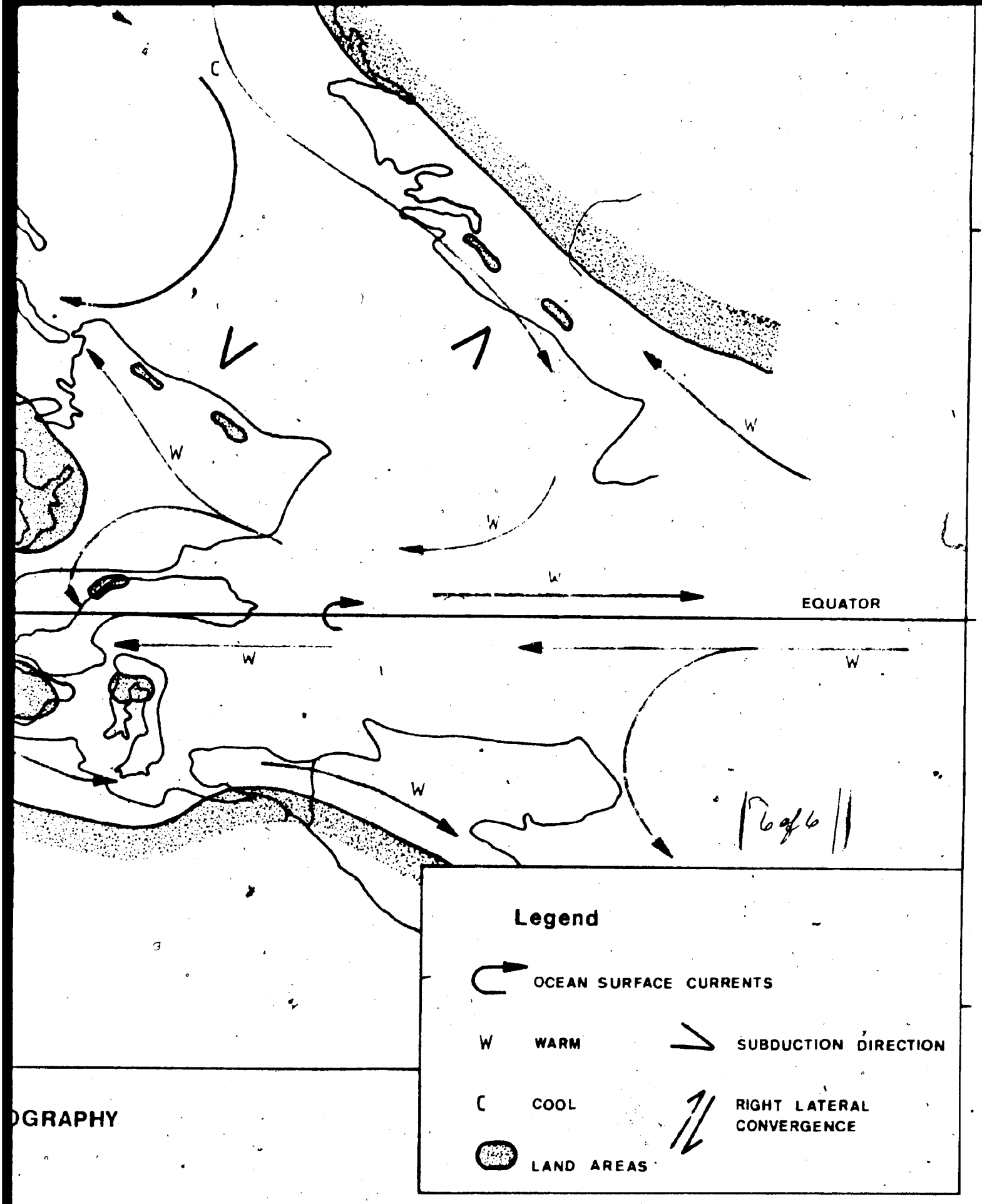

C
C
3oF
W
W
W
W
W
W
W
EQUATOR
Legend
OCEAN SURFACE CURRENTS



TEXT-FIG. 5.3 LATE DINAN



5.3 LATE DINANTIAN PALAEOGEOGRAPHY


C
W
W
W
W
W
W
EQUATOR
W
W
Legend
OCEAN SURFACE CURRENTS
W WARM
SUBDUCTION DIRECTION
C COOL
RIGHT LATERAL CONVERGENCE
LAND AREAS

OGRAPHY

321 Pocket